POPULAR RESEARCH NARRATIVES

VOLUME III

Fifty brief stories of research, invention or discovery, directly from the "men who did it"

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GENERAL JOHN J. CARTY

Vice-President, American Telephone and Telegraph Company. Engineer, Inventor and Leader in Research. Past-President and Honorary Member, American Institute of Electrical Engineers. John Fritz Medalist. Brigadier General U. S. Army Reserves; Distinguished Service Medal. Member, National Academy of Sciences, etc.

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PEACE AND PLENTY THROUGH SCIENCE

By John Joseph Carty, Sc.D., LL.D., D.Eng.

Vice-President, American Telephone and Telegraph, Company; Engineer, Inventor and Leader in Research; Past-President and Honorary Member, American Institute of Electrical Engineers; John Fritz Medalist; Brigadier General, United States Army Reserves; Distinguished Service Medal; Member, National Academy of Sciences, etc.

The publication of Popular Research Narratives does more than provide scientific reading in an entertaining and instructive manner. They constitute in themselves a distinct contribution to the cause of scientific research because they present to the reader in authentic form, concrete examples of the methods, vicissitudes and triumphs of scientific research. They should be read by the general public, and all of those who are interested in the cause of science should encourage their widest possible circulation.

The progress of scientific research in our country depends in the last analysis upon the support which it receives from the public. There is no lack of problems to be solved, all of which in one way or another affect the welfare of the Nation, and there will be no lack of competent scientific investigators who will solve them if the necessary financial support is provided.

It is sometimes instructive to appraise the value of scientific research in pecuniary terms. For example, take the very great improvements in electric power and electric lighting which have been made by the industrial scientists during the past twenty-five years. Were it not for these improve-

ments the bill which the public is now paying for electric current would be greater by more than *two billion dollars* a year. A similar story could be told of the results of scientific research conducted in the telephone industry and in the chemical and metallurgical industries.

But the higher values of scientific research must be stated in terms of human achievement, the elimination of poverty and disease, the advancement of learning, the growth of right living and good understanding among men. Scientific research is indispensable to the attainment of all of these ends.

According to the vision of Science life must no longer be regarded as a struggle among men for a limited store when one man's gain or one nation's gain must be another's loss. Under the banner of scientific research we are asked to join with our fellow men working together in controlling and utilizing the boundless forces of Nature. Such is the message of Research Narratives.

American business and commerce and industry and the American public should be urged to give to scientific research in our universities and elsewhere that support which it so greatly needs. "Science" said the great Pasteur "is the soul of the prosperity of nations and the living source of all progress." For all of the benefits which it confers upon us Science asks only that we provide its zealous workers with the opportunity to multiply their efforts in our behalf.

WHY THE NARRATIVES?

Many interesting stories are connected with the inventions, discoveries and researches which have given us telephones and radios, electric light and power, automobiles and aircraft, tools and toys, and other blessings innumerable. As the sciences advance and as engineers and chemists make new knowledge useful, their successes and failures become materials for new stories. But scientists and engineers who have time and skill for writing stories in language which most of us can enjoy are "rare birds."

Research Narratives are collected from researchers and inventors who are making life richer and pleasanter. They are put into laymen's language very briefly, in order that thousands of persons may enjoy these stories, get useful information and know a little more about the ways in which scientists and engineers are serving their fellowmen.

What is Engineering Foundation? An institution of men and funds for aiding research to make the riches of Nature useful to men. This Foundation was established in 1914 by our senior national societies of Civil, Mining, Metallurgical, Mechanical and Electrical Engineers. It was suggested by Ambrose Swasey, of Cleveland, Ohio, who loved his human brethren and the stars and helped to bring them together by building great telescopes. He gave the first funds for the Foundation. Other persons who have benefitted from engineering are adding to its resources for helpful service to mankind.

ALFRED D. FLINN,
Director.

WHO "MAKES MONEY"?

Many persons credited with "making money" really accumulate wealth created by others. Who create wealth? Toilers, including the mental workers. Among them are engineers, whose ideas take form in railroads, automobiles, ships, airships, highways, bridges, canals, harbors, power plants, lights, telephones, telegraphs, radios, buildings, waterworks, in machines and their countless products, in manufacturing processes, and in tools making more fruitful the work of many artisans. Both creation and accumulation are essential to progress.

Engineering is essential for the health, wealth, safety, and the very existence of modern communities. It promotes America's highest ideals, security and happiness, and enriches her contribution to the world. You are concerned.

BUDGETS AND BRAINS

In these days of automatic machinery and mass production, of increasing sizes and speeds and pressures, of rising temperatures and of higher voltages, engineering researches are enterprises of real magnitude. Money without mind is inert. Industries without research are in peril. Brains without budgets can no longer conduct research on the scale demanded for prosperity of business and security of credit. And modern research in applied science requires time, for its problems are no longer simple.

The national engineering societies can supplement money given to Engineering Foundation with the mental resources of their members collectively and individually. This union of mind and money makes both productive for the good of mankind.

DISTANCES OF THE STARS

Methods of Measurement

S. A. MITCHELL

Land surveyors commonly walk between points dragging along their measuring tapes. When rivers or other impassable obstacles intervene, or when distances are great, as between two mountain peaks, surveyors often use transits or theodolites, instruments equipped with telescopes and graduated circles, and measure angles. Then with the aid of a conveniently measured distance as a "base line" and the principles of trigonometry, they compute the distances desired. For quite obvious reasons trigonometric measurement is the only direct method available for star distances.

As the only available base line, the astronomer uses the diameter of the earth's orbit, a distance of 186,000,000 miles. This is an enormous distance by terrestial standards but almost infinitesimal when compared with the colossal distances of the fixed stars, for the nearest of these stars is so far away that it takes light, traveling at 186,000 miles per second, 4.4 years to reach us. According to recent work at Mount Wilson Observatory, the light from the Andromeda nebula takes one million years to reach the earth.

Measurement of distances is based on a unit distance, for example, a standard foot, or a standard meter. Instead of a foot rule, the astronomer uses a light-year, for even so long a unit as the mile gives inconveniently big numbers for distances outside our solar system.

Astronomers determine the distances of stars by measuring

the sizes of their parallaxes. The parallax of a star is the angle at the star between two lines, one drawn to the sun and the other to the earth. These angles are very small. Their measurement taxes the resources of modern astronomy, since for the nearest of the fixed stars the parallax is less than one second of arc.

Not until 1833 was the first stellar distance recorded. In that year, three astronomers independently measured the distances to three stars, using instruments of three different types and three different methods. All these methods, by eye observations, required prodigious labor. So great were the difficulties that by 1910 approximate distances had been determined to not over 100 stars. Meanwhile, photography was being applied, bigger and much better telescopes built and other advances made in the optical art, greatly increasing accuracy. A new era in parallax work arrived when photography was applied.

In 1900, Ritchey showed how to use the great 40-inch refracting telescope at Yerkes Observatory for photographing. In 1903, Schlesinger inaugurated the determination of stellar parallaxes with this equipment, the largest in the world. The average probable error of modern photographic parallax work is less than one-hundredth of a second of arc, (one-360,000th part of a circle). Seven great observatories in the United States and one in England are cooperatively engaged in parallax work. At Mount Wilson both the 60-inch and the 100-inch reflecting telescopes are being utilized. Schlesinger's 1924 catalog contains trigonometric parallaxes of 1870 stars.

In the past decade, great energy has been spent in determining distances of stars by indirect methods. Most important are:

A. Spectroscopic parallaxes, derived by estimating the relative intensities of various lines in stellar spectra. This method was inaugurated at Mount Wilson by Adams and Joy, *where spectroscopic parallaxes of 2500 stars have been* determined. Harvard and Victoria observatories in America and the Lockyer in England have been following the same methods.

B. Dynamical and Hypothetical Parallaxes. Jackson and Furner, Russell and others have investigated the orbital motions of double stars, and on the assumption that each star of the double has the same mass as the sun, or the double star system twice the mass of the sun, have derived parallaxes.

C. Statistical Parallaxes. Many years ago Kapteyn showed that a correlation existed between the size of the parallax of a star and other observed quantities, chief of which were proper motions. All indirect methods rest on certain assumptions. Hence, indirect parallaxes can represent the truth only in so far as their results agree on the average with trigonometric parallaxes as determined by the best of modern photographic work. Trigonometric parallax observers must continue their work until sufficient numbers of stars have been observed to standardize the parallaxes *derived by indirect methods. Such a time* is *not yet* in sight.

But "what's the use?" To increase Man's knowledge of himself, his vast environment and his Creator, by whatever name mentioned. Knowledge gained from the stars, including our Sun, is aiding Man to measure time, to feed the great and rapidly increasing population on the Earth, and to satisfy the innumerable other necessities of modern civilization.

The most important link in the chain of progress toward perfecting our ideas of the stars seems still to be the accurate determination of stellar distances. The great problem of astronomy, the evolution of the stars and the structure of the universe, can find solution only through an intimate study of the constitution of matter. The size of an atom can be deduced from observations of giant stars. Stars are laboratories, inaccessible to physicist and chemist, wherein great changes of temperature, pressure and electrical conditions may be studied at will, by means of telescope, spectroscope, photographic plate and microscope.

Contributed by S. A. Mitchell, Professor of Astronomy at the University of Virginia and Director of the Leander McCormick Observatory, University, Virginia.

CONTOUR MAPPING FROM THE AIR

A Mechanical Process

BROCK AND WEYMOUTH

Tradition at an Eastern summer engineering school sends Freshy to the instrument house for a "contour finder." This magical instrument presumably will pursue the intersections of level planes with the ground surface, thus mechanically locating lines called contours, used on maps to show elevations and slopes of the ground. Details are left to Freshy's imagination and the instructor in charge of instruments. Freshy finally gets introduced to transit, stadia rod, and other means of tediously making sufficient ground measurements to approximate the locations of contours and other features.

Ever since airships and cameras became practical, topographers have looked to them as means for better and more rapid mapping. The Brock process now affords mechanical means for making topographic maps. The special stereoscope developed is a contour finder exceeding the fondest hopes of the engineering freshman. With a pair of aeroplane photographs viewed through this instrument, the ground stands out in bold relief and one contour after another can be accurately marked on the plates. Aside from the speedy performance of flying, a few base-line measurements to give scale, and a small number of elevations for vertical control, the work is done in the office. Here it can be speeded by parcelling out to different operators, who work under conditions more conducive to accuracy than those ordinarily encountered in surveying by old methods.

This process to a large extent substitutes operations mechanical in their nature and accuracy for practices involving human errors. In its development many instruments were designed, built and tried out by the Arthur Brock, Jr. Tool & Manufacturing Company. Machines for the translation of photographic information to the form of accurate topographic maps must not only comply rigorously with mathematical principles, but numerous mechanical limitations must be met and a constant standard of mechanical accuracy attained. The research was based on a determination to produce a process strictly correct in theory, quick and accurate in practice, mechanically simple and self-checking, and commercially feasible.

Development passed through four stages. The first, used in the World War, was the simple union of aeroplane photographs to form a mosaic picture. Such a mosaic is often

called a map, but is not an accurate map for numerous reasons. As the aeroplane banks or pitches, the camera tilts and the views are distorted. Pictures taken from different altitudes cannot be fitted together. Even with camera vertical and plane at constant height, the pictures will not have the uniform scale essential in accurate maps, because of differences in ground elevation. In conical projections, as photographs are, each ground elevation has a scale in accordance with its distance from the lens.

Difficulty due to tilt led to the second stage of investigation, search for mechanical means of keeping the camera vertical. After years of effort, the Brocks concluded that the best that antifriction suspensions or gyroscopic devices could do was the minimize the tilt. Nor is it possible to read the angle of tilt on such indicators as spirit bubbles; these, too, are affected by motion of the aeroplane.

Extent of tilt is necessarily recorded in the pictures. If only there is available sufficient information of the ground pictured, the tilt can be computed. Why not make ground measurements so that each picture can be solved? This was the third stage. Thus, if three points appearing in the picture are of equal elevation and the distances between are known, it is possible to compare this known ground triangle to its pictured representation and by computation reach a conclusion respecting the plane of the plate when exposure was made. This, however, involves expensive work that must be repeated for the area covered by each plate exposed, and the mathematical operation is not entirely satisfactory. Efforts to deal with the single picture alone were abandoned.

Finally, a happy solution was hit upon by treating the

aerial views in pairs under the stereoscope, where at one time the relations of both pictures are determined. The stereoscope provides for highly refined measurement of the displacements of points on the pictures due to the conic projection. There are required a few elevation differences; the points need not be referred to any particular datum, nor must they lie in any particular plane, but are selected simply for convenience from the pictures themselves. Discrepancy between machine readings for these points and their proper displacements as computed for conical projection indicates the degree and direction of tilt in the pictures.

The plates are then reprojected so as to eliminate these defects. Reprojected plates are again treated stereoscopically to determine by similar readings the elevations of any desired points. By such measurement and the stereoscopic vision, the contour lines of any desired elevation can be rapidly run out on the plate. Finally, by means of another special machine the different contours and other features are projected to the uniform scale desired on the finished map. This fourth stage has been rewarded by the development of a process making possible accurate contour maps of any kind of country in a fraction of the time required under old methods.

Based on information supplied, on request, by Brock & Weymouth, Inc., Philadelphia, Pennsylvania.

TIME SAMPLING

A Device Insuring Accuracy and Honesty

D. W. BRUNTON

A sample is a small portion that accurately represents the whole. To sample a homogeneous fluid or solid is easy, but to sample precious metal ores is difficult, for they are heterogeneous. Ore as received at mill or smelter may be coarse or fine, wet or dry, rich or poor, and often ranges through all these conditions; its particles vary from worthless gangue to flakes of gold.

To determine a basis for payment for the ore and the process for getting out the metals, accurate sampling is necessary; but to physical difficulties human limitations and dishonesty are added. Early simple methods of sampling proved inadequate. Shovel-sampling was throwing from the car or wagon into a separate pile every third, fifth or tenth shovelful. Conscientious, careful shovelers might get fair samples; but some shovelers were neither, and some employers of shovelers were unscrupulous. Cornish quartering, almost universal a generation ago, gave fair samples when carried on with skill, care and common honesty; but there were possibilities of accidental errors and opportunities for clever manipulation. First ore was piled in a cone; but dropping shovelful after shovelful on top of a cone partially separated the coarse particles instead of mixing. Successful juggling could so arrange the cone that when it was flattened into a "pancake" and then quartered the quarters would have distinctly different proportions of coarse and fine, of rich

and lean ore. Alternate sectors of the "pancake" were taken for the sample and the others discarded. These operations were repeated until the sample was small enough for the assay office.

In smelting lead or copper ores containing gold and silver, a very high percentage of the metals must be gotten out in order to make the operation commercially successful. In the fusion zone of the furnace the mass should be sufficiently fluid to allow metallic particles to settle through it like mist condensing into rain and falling to the earth. To establish this desired condition a definite chemical composition of the "charge" is necessary. Sometimes this condition can be attained by adding fluxes, like iron and lime; but fluxes cost money. Therefore nearly all successful custom smelters are located at railroad centers, where they can draw ore from a great number of mining districts. By skill and care they can buy a mixture of ores which will make possible the necessary chemical combination without admixture of dead flux. Before the ores are purchased, they must be correctly sampled and chemically analyzed.

Need for more accurate and cheaper sampling brought into use various systems based on taking a portion of the crushed ore from a falling stream. This method, although much better than the Cornish, gave results far from accurate; no falling stream of ore is homogeneous throughout its width no matter how carefully it may be fed into a vertical or inclined spout.

The next step was to take the entire stream for parts of the time. It is not practicable to produce a stream of pulverized ore constant in value throughout its length, any more than it is possible to have the stream homogeneous

across its width; but it was discovered that by taking a small portion entirely across the stream at very short intervals, the average of thousands of these small portions gave a sample so nearly correct that results could be duplicated almost exactly. Thus if a falling stream of ore were deflected into bin A for one-fifth of a second and into bin B for four-fifths of a second, bin A would receive a 20 per cent portion, which, if the operation were continued for a long time, would be an accurate sample. Sampling would be a function of time and not of quality, independent of the physical condition of the ore, whether wet or dry, coarse or fine, rich, or poor.

Almost coincidental with the discovery that accurate samples could be obtained by taking all of the stream for a portion of the time, came great improvements in rock-crushing machinery, thus affording possibilities of constructing more satisfactory samplers than could have been built 20 or 30 years ago.

At first mechanical sampling machines were complicated, but as is usual in inventions, simplification and other improvements came as their use was extended. Today a time-sampling machine is almost indestructible and will operate for years without appreciable wear except on the cutting edges of the intake spout, which are usually made of saw steel and so designed that they can be readily replaced. When this method of sampling is used on all the ore coming into a metallurgical plant and the various products, including the tailings, are sampled in the same manner, it is possible to account with almost unbelievable accuracy for all precious metals received, and to show their exact paths as they leave the works.

Numerous devices for mechanical sampling were invented, each a gain over hand methods. Finally, discovery of the value of time as a fourth dimension in measuring the value of ores enabled an inventor to construct simple, durable, practical machines which produce very accurate samples. Furthermore, the process could be so arranged as to prevent dishonest manipulation. By locking and sealing the apparatus, access to the ore being sampled could be prevented, and the sample delivered into a "safe" directly attached to the time-sampling machine. Absolute protection against dishonesty and error is unattainable, but science and invention have come close to the goal in sampling ores.

Contributed by D. W. Brunton, Member, American Institute of Mining and Metallurgical Engineers, Denver, Colorado.

CAST IRON PIPE

Conveyor of Water for Civilized Communities

H. Y. CARSON

For a century, pipes made of cast iron have been used more extensively than any other kind, in western Europe and America, for conveying and distributing water to communities. Pipes of this material, laid in trenches in the ground in 1665, still supply water to the fountains of Versailles. Philadelphia has cast iron pipes reported to have been in service for more than a hundred years. In many other communities also cast iron pipes have given good service for long periods. But like other objects of iron, pipes are the prey of corrosion.

Though cast iron pipe rusts on the surface, seldom pitting or scaling off, yet corrosion reduces the capacity of pipes for carrying water, sometimes forming rough lumps of rust, called tubercles, inside the pipe. Not only do the tubercles reduce the bore of the pipe, but they also cut down the water-carrying capacity by their roughness, acting as a friction brake on the flowing water. Tuberculation proceeds rapidly at certain stages and under certain special conditions of water. Sometimes these tubercles so nearly fill small pipes after a number of years, that but little water gets through.

Devices for scraping the rust from the insides of pipes have been mechanically successful, but it has been a common experience that some of the pipes tuberculate again in shorter time than they did originally.

It has long been known that cement, now so familiar in highway pavements, sidewalks, bridges, buildings, and water reservoirs, would inhibit tuberculation of iron embedded in it. Also, cement can be given a very smooth surface. Years ago, water pipes were made of thin sheet iron lined and covered with cement mortar. Pipes of this kind did good service for a period, but, owing to structural weaknesses, they have passed out of common use.

The problem resolved itself into getting a thin, smooth, strong coating of cement on to the inside of cast iron pipes of all sizes, and making the coating stick so tenaciously that it would withstand the hard bumps of transportation and of laying in the trench. The coating must cover every spot of the interior of the pipe.

Charleston, South Carolina, like many another city, due to the nature of its water, experienced for years a material

reduction in the carrying capacity of its cast iron pipes. This loss was most readily observable in the 24-inch main, 12 miles long, from the pumping station to the center of the distribution system. It increased the coal bill for pumping, reduced the quantity and pressure of water in the city, and hastened the time when more money must be invested in pipes.

The pumping main had been cleaned three times. Each time its capacity was restored substantially to that of a new pipe, but after each cleaning the loss increased rapidly. Following the last cleaning, 80 per cent of the benefit had disappeared in thirty days. Pipe that would not tuberculate so badly was much needed. Consequently, in 1921, J. E. Gibson, Manager and Engineer of the Charleston Water Department, worked out with the Research Department of the American Cast Iron Pipe Company the possibility of using standard cast iron pipe lined with cement mortar.

The Company built an experimental plant and undertook to make cement-lined cast iron pipe. At first, Rosendale, or "natural," cement was used, the coating being $\frac{3}{16}$ inch thick in pipes 4 to 10 inches in diameter and $\frac{1}{4}$ inch thick in 12-inch to 24-inch pipes. Natural cement was preferred in the beginning because quicker setting and less subject to shrinkage and hair-like cracks. Each pipe (12 feet long) was stood on end with an iron cone, point up, at the bottom. Cement mortar in just the right condition was poured into the pipe around the cone. The cone was then drawn up out of the pipe, distributing the mortar into a thin, dense, smooth coating.

During 1922 and 1923, the process was much improved. Portland cement was substituted for the weaker natural

cement. The pipe, open at both ends, is now placed with its axis horizontal on revolving rollers. A rich mixture of cement of proper consistency is distributed over the interior surface of the pipe while it is being revolved. After the cement is uniformly distributed, the pipe is rotated at a higher speed for about 25 seconds.

These changes make possible a thinner, denser and more strongly adherent lining. Incidentally, it was discovered that the jarring vibration of the pipe as it was rapidly rotated drew some of the water in the mortar to its inner surface, thus making the inside of the pipe almost as smooth as porcelain.

Apparently this engineering investigation has yielded an acceptable solution of an old waterworks problem, increasing the durability and service value of cast iron pipe, and, above all, preventing loss of capacity through tuberculation.

Contributed by H. Y. Carson, Member, American Society of Civil Engineers, Research Engineer, American Cast Iron Pipe Company, Birmingham, Alabama.

SUPER-CONDUCTING COPPER

A Tantalizing Laboratory Achievement Which May Lead to Industrial Economies

L. A. HAWKINS

Professor A. E. Kennelly, in his Research Narrative, "A Retrospect in Research," tells how Lord Kelvin in 1857 found that copper wire used in cable manufacture differed much in conductivity, and urged that trans-atlantic cables

be made of high-conductivity copper—chemically pure metal, capable of transmitting current with much less loss than occurred in the usual, more or less impure, copper. This was one of the early applications of research to finding better electrical conductors.

From that day to this, pure copper has been used almost exclusively for electrical transmission. The only known material with higher conductivity than pure copper is silver, a metal too costly for use in line wires.

But in spite of this settled practice, interesting questions remained. Why is silver more conductive than copper? Why is copper, next to silver, more conductive than all other metals? Is its conductivity absolutely a fixed thing, or is it susceptible of increase by special treatment?

A small increase in the conductivity of commercial copper would have great value. An increase of even 10 per cent would release for other fields an enormous tonnage of copper now used for transmitting power. The economic radius of all existing transmission systems would be increased 10 per cent, increasing by 21 per cent the area served; or the underground cable subways of cities, so many of which are taxed to capacity with their loads of today, could without enlargement carry additional loads of 10 per cent.

So, when Dr. W. P. Davey, of the research laboratory of the General Electric Company, found by calculations, based on the arrangement of the copper atoms which the X-rays revealed, that copper composed of a single crystal should have a conductivity 14 per cent greater than ordinary copper, greater than that of silver, possibilities of great scientific interest were disclosed. In order to check his calculations, Dr. Davey proceeded to devise apparatus for producing large single crystals of copper.

The single crystals were made by very gradually heating and cooling pure copper in an electric furnace. When molten metal is quickly cooled, very small crystals are formed; if the melt is cooled slowly, the crystals are larger. Dr. Davey cooled the melt so slowly that only one crystal was formed, and that included all of the metal. By this method he was able to produce single crystals three-fourths of an inch in diameter and six inches long, and one that is fourteen inches long.

The conductivity of these crystals was then measured, and, although the quantities involved were only 36/100,000ths of a volt and 18/1,000,000ths of an ohm, measurements by different methods were made which checked within one quarter of one per cent. The measured conductivity was 113 per cent that of pure copper of many crystals, within one per cent of the calculated value.

In a crystal, the atoms—the unit particles of the substance—are built up in regular fashion. The crystals of copper, for example, are made up of very tiny cubes, with atoms of copper at the corners and centers of the faces of each unit. The large crystals grow in such a direction that the atoms are arranged in columns along the length of the crystal. It is this regular arrangement of the atoms, which, it is believed, gives to the single crystals their superior conductivity when compared with ordinary (polycrystalline) copper, in which the crystals are small and the arrangement of these small crystals quite chaotic.

There is reason to believe that the conductivity of copper crystals along another axis from that measured may be even 60 per cent greater than the value for pure polycrystalline copper, but the growth of single crystals along this other axis has not yet been brought under control.

Unfortunately, there is no immediate prospect of utilizing commercially this newly discovered high conductivity, for the single crystals are very delicate and difficult to manufacture.

One of the first facts discovered about single-crystal copper was that the specimens could be bent double with one finger, but that strength was required to straighten them afterwards. A crystal of the size of a lead pencil, if given a jerking motion, bends like a stick of soft wax. Having been once bent, however, it acquires the properties of ordinary copper, for the bending has transformed the large crystal into a mass of smaller ones.

Contributed by L. A. Hawkins, Member, American Institute of Electrical Engineers, Engineer, Research Laboratory, General Electric Company, Schenectady, New York.

THORIATED TUNGSTEN TUBES

A Forward Step in Radio Transmission

L. A. HAWKINS

Two great objectives of scientific research are elevation of human life and saving of human lives. In darkness of night and shroud of fog, April 14, 1912, The Titanic struck an iceberg. Unwarned, 1500 human beings went down. This appalling loss shocked civilized nations into endeavors to minimize the possibility of such catastrophes.

January 20, 1914, at the International Conference on Safety of Life at Sea, the United States of America was asked to undertake the ice patrol of the North Atlantic. Charged

with so great a responsibility, our Government has constantly been alert to utilize every aid which science could afford.

Not many months ago, two Coast Guard cutters, the Tampa and the Modoc, employed in the patrol, were equipped with the highest powered telephone and telegraph radio transmitters carried by any ship under the American flag. These transmitters contained recently invented thoriated tungsten tubes.

Thorium was one of the substances found to be radioactive, soon after Becquerel's discovery of radioactivity and the finding of radium by the Curies. See Narrative Number 13. Narrative Number 14 was a short chapter from the story of tungsten. The present invention combines these two metals for new usefulness. Tungsten is now a household friend in electric lights, and thorium in one of its forms illuminates many a watch face.

Success for the ice patrol consists not only in finding the bergs, but also in conveying quickly to ships at sea exact information of the whereabouts of these menacing floaters. Most ships traversing the Atlantic are now equipped with radio apparatus; hence the fitting of these patrol boats with the best radio transmitters which could be produced.

For the purpose of providing dependable, long-range, high-powered transmitters, the Coast Guard commissioned the General Electric Company to develop a transmitter especially for the ice patrol. The equipment had to be so compact that it would fit into a small radio room. Due to its compactness, the voltages generated were required to be minima and the panels to be all the "dead front" type so that the operator would not be exposed to dangerous voltages if thrown against the apparatus in heavy seas.

Strength, reliability and simplicity of tuning also were demanded. The emitted wave length, or frequency, must be absolutely independent of variations due to rolling and pitching of the ship. All these requirements were met.

Greatest among the problems was the development of a high-powered, low-voltage vacuum tube. Available were low-voltage tubes using up to 2000 volts direct current obtained from a motor-generator, and high-voltage tubes operating on 10,000 volts or more of direct current. To have provided this latter high voltage on shipboard would have required a motor-generator set, a step-up transformer, a rectifier with two or more kenetron tubes, and an elaborate filter to smooth out the ripple in the rectified wave.

Research specialists produced a new tube rated at only 2000 volts on the plate, but four times as powerful as previous low-voltage tubes. Its output is 1000 watts. By means of this tube, power is supplied from the direct-current motor-generator set, eliminating the transformer, kenetron, rectifier and filter, heretofore necessary.

Ice patrol warnings from this equipment, while reaching much farther than ever before, will no longer be a source of interference with commercial traffic and broadcast entertainment. Under favorable conditions, it is expected that direct communication will be had with headquarters in Washington.

Discovery and development of thoriated tungsten for this purpose resulted from the combination of a scientific investigation and a happy accident. Investigation of the so-called "Edison effect" in incandescent lamps by Dr. Irving Langmuir led to a more searching study of factors governing emission of electrons from hot filaments.

In one series of experiments with tungsten filaments, as

the vacuum was made higher and higher, electron emission unexpectedly became steadily greater until finally, when the bulb was immersed in liquid air, the emission was ten thousand times its original value. This was an astonishing result; but, when the experiments were repeated with another lot of wire, no such increase in emission developed.

An investigation of the two lots of wire revealed the fact that the second was pure tungsten, but the first contained thoria, often used in lamp filaments to prevent excessive grain growth on burning, which induces fragility. This enormous increase in emission would not have been observed under other than the very special conditions of the experiment.

Further study disclosed the fact that, when a tungsten filament containing thoria is operated under the right conditions, the thoria is reduced to thorium, which diffuses to the surface and there forms a continuous layer one atom deep. The electron emission is then that of thorium which is much higher than that of tungsten, while the high affinity of thorium for tungsten prevents the surface thorium from evaporating as it would if the whole filament were thorium.

If by accident the filament is overheated, and the surface layer of thorium is evaporated, the filament may be "reformed" by running it at high temperature for a short time, so as to cause more thorium to diffuse to the surface, and then bringing the temperature back to normal.

Because of the high electron emission of thorium, a thoriated tungsten filament is very efficient, so that in the small sizes used in receiving tubes a number of filaments may be run from a set of dry batteries without unduly shortening the battery life. In power tubes, with large filaments, the life

is very great because of the low operating temperature of the filament, which the emission characteristics of thorium make practicable.

Based on information supplied upon request by L. A. Hawkins, Member, American Institute of Electrical Engineers, Engineer in Charge, the Research Laboratories of the General Electric Company, Schenectady, New York.

PICTURES BY PHONE

Another Means for Transmitting Information

EDWARD B. CRAFT

Are we near realizing the Irish immigrant's conception years ago of the possibilities of the telegraph? Told that it carried messages to persons far away, he responded to a distant brother in need of shoes by hanging a pair on the wires. Matter having been reduced to charges of electricity, may we soon transform it into currents and transmit portions in desired forms to any destination? Such thoughts are provoked by successes in sending pictures by telephone across a continent.

In connection with a meeting of Engineering Foundation last May, Vice-President Frank B. Jewett, of the American Telephone and Telegraph Company, presented to the Founder, Ambrose Swasey, and to the presiding Vice-Chairman, Edward Dean Adams, perfect untouched photographs of themselves, transmitted over a telephone circuit 3305 miles long, between New York and San Francisco, in seven and one-half minutes.

Over suitable circuits there can be sent any distances pictures of all subjects which can be photographed—persons, landscapes, structures, machines, drawings, manuscripts, fingerprints—even colored pictures. A picture sent electrically is a faithful copy of the original.

Prominent among developments which have facilitated picture transmission are photoelectric cells, vacuum tube amplifiers, electrical filters and carrier currents. In simplest terms, there are demanded means for translating lights and shades into some characteristic of an electric current, an electrical channel capable of transmitting this characteristic faithfully to destination, and means for retranslating the electric current into lights and shades corresponding in relative values and positions to those of the original.

To meet the first of these demands the photoelectric cell is used. This is a vacuum tube with but two electrodes. One of these, the cathode, is of potassium, or some other alkali metal, which gives off electrons when light falls upon it. This flow of electrons creates a current through the wires, whenever they are connected to a suitable circuit, directly proportional to intensity of illumination of the cathode.

Vacuum tubes for amplifying and other purposes scarce need an explanation in these radio days.

Carrier currents are alternating currents made to vary in accordance with the variations of other currents representing the telephone or telegraph message and are so called because they may be said to carry the currents by which they are controlled. They will also "carry" the varying current from the photoelectric cell. Electrical filters separate at terminals the several carrier currents going over one circuit.

A suitably regulated telephone circuit has been found the

best practically available electrical channel for pictures. The great network of the Bell System affords remarkable facilities for this service.

Any picture consists of a large number of small areas, each of substantially uniform brightness, but differing one from another more or less. These differences of brightness, or light and shade, must be made to affect the intensity of the light falling upon the cathode of the photoelectric cell. The picture is therefore photographed on a standard film, which is rolled into cylindrical form, mounted on a carriage, moved parallel to its axis and rotated, with exactly timed motions. The photoelectric cell is placed inside the film cylinder.

Thus a direct current of varying intensity is produced. It is amplified and made to modulate an alternating current which is the carrier of the characteristics of the photo-current. Along with the carrier current goes over the phone wire a current which exactly synchronizes the sending and receiving cylinders. These two currents are separated by the electrical filter.

At the receiving end a sensitive film on a cylinder, properly enclosed, travels at precisely the same rate as the sending film. An enclosed electric lamp projects a small spot of light through lenses and a slit onto this film. A "light valve" modulates the light passing this slit. This valve's principal parts are a magnet and a narrow ribbon-like conductor, through which the current flows.

Interaction of current and magnetic field moves the ribbon rapidly, exposing the slit, and varying the intensity of the light as it traces on the film close together fine lines of uniform density and varying width, or of uniform width and

varying density, according to the system adopted. Prints from negatives by the latter system with 100 or more lines to an inch may be retouched, reproduced or treated otherwise like ordinary photographs.

As to uses, let your imagination run; they are too numerous to be listed here. There were attempts to transmit pictures by telegraph in 1847; others followed, by various methods, in England, France, Germany and the United States. By 1907 fair success had been achieved in Europe, but difficulties arose. Transmission by wireless telegraph also was attempted, with indifferent results. Personal disappointments and successes have been many along the way to present readiness to serve a large public.

Like most notable recent scientific achievements, picture transmission has been built on knowledge and experience of pioneers, by groups of highly trained researchers, in well-equipped laboratories, supplemented by engineers in shop and field. Prominent among the workers of the Bell System have been Herbert E. Ives, J. Warren Horton, R. D. Parker, Alva B. Clark, Maurice B. Long, and Edward C. Wente.

From information contributed by Edward B. Craft, Member, American Institute of Electrical Engineers, Executive Vice-President, Bell Telephone Laboratories, Inc.

COMMON SALT IN METALLURGY

USE OF CHLORINE FOR RECOVERING SILVER FROM ITS ORES

STUART CROASDALE

Silver, first obtained in natural metallic masses, was later produced also from ores, in which it was chemically combined with other substances. As centuries rolled by, improvements were made, but even in the twentieth century, new processes have been introduced and, possibly, "the best is yet to come," as Science continues its progress.

Chlorine came to be an important agent for separating certain metals from their ores. It was first obtained and its properties first examined by Karl Wilhelm Scheele, a Swedish chemist, in 1774, but not until 1810 did Sir Humphry Davy, of England, satisfactorily prove its elementary nature and name it from the Greek word meaning greenish yellow. All chlorine used in metallurgical and other industrial processes is derived primarily from common salt. It is a greenish yellow gas and a very active chemical reagent. It was the first gas used in the World War.

Chlorine is usually liberated from salt (chloride of sodium) by means of the sulphuric acid radical* or by electrolysis. In metallurgy it may be generated during a process and used in the nascent, or atomic, state, or it may be generated by a separate operation prior to utilization and supplied as a gas in the molecular state.

Use of chlorine in metallurgy was first recorded in a treatise

* A radical is a group of different atoms acting in a compound like a single chemical element.

by Vanoccio Biringuccio, "De la Pirotechnia," Venice, 1540. He stated that ore (previously roasted, if refractory) was finely ground in a stone mortar, screened wet, and dried. Dry ore was moistened with vinegar or water, in which had been dissolved corrosive sublimate, bluestone (copper sulphate), common salt and sometimes copperas (sulphate of iron). This mixture was then covered with mercury and ground, or stirred, in the mortar for an hour or two. Then the gangue (waste portion of the ore) was washed away with water, and the silver, having alloyed with the mercury, was recovered by retorting this amalgam.

The nature of chlorine and the chemical reactions were then wholly unknown. Nevertheless, this process has remained in continuous use without material change. It was the basis of much of the early silver production in South America, Mexico and the United States. In this process the sulphuric acid radical of the bluestone liberated the chlorine of the common salt to form the chloride of copper, which not only converted the silver in the ore into silver chloride, but probably also reacted with the mercury to form the chlorides of mercury, which likewise helped decompose the silver minerals. After the silver had been converted into the chloride, it readily alloyed with the mercury, forming amalgam, and was recovered as bullion by distilling off the mercury.

In all probability, the first metallurgical operations by Europeans on the American continent were conducted by the Patio process, invented in 1557 by Bartholome Medina, a miner of Pachuca, Mexico. The Spaniards came to America primarily to exploit its gold and silver deposits. They accumulated all the gold available from the Indians, but this

was only native, or placer, gold that had been found in the stream gravels.

These Spaniards were good miners and soon discovered that silver was more plentiful than gold in Mexico, but the silver ores needed chemical treatment. Mines were usually in arid regions, where water had to be conserved. Transportation was by mules over the crudest and roughest trails. Supplies were scarce and those used must be as condensed as possible. Every possible advantage of local conditions had to be taken.

If the silver ore did not contain sufficient copper to form the bluestone, a vein of copper was usually found in the vicinity that would supply this chemical by ordinary open-air roasting. Salt had to be "packed in" from the coast. Mercury was undoubtedly brought from Spain, but was largely recovered by retorting the amalgam.

The scope of operations was enlarged to treat the lower grade ores and keep down expense. The stone mortar was replaced by the arrastre which was really a mortar four or five feet in diameter made of blocks of granite or other hard rock set in the ground. The pestle was a boulder or block of granite fastened to a radial arm on a post, set in the center of the arrastre, and drawn by a blind-folded mule. Ore-grinding was similar to pugging in brick-making. If native gold was present in the ore, it was recovered by adding mercury to the arrastre during grinding.

Medina's process was designed to meet local conditions. Its chemistry was essentially that already described. It is stated that he got his ideas from Spain. Instead of completing the process in a stone mortar, the pulverized ore was mixed with water to form a thin mud and then spread into

huge "mud pies" on a paved area, or patio. Salt, bluestone and mercury were mixed with the ore by tramping with men or mules, the treatment lasting from three to six weeks.

Then the gangue was washed away and the silver was recovered from the amalgam. Medina's process is still used in the more isolated mining districts of Mexico and is yielding a high recovery of silver from the ore. Advances in chemistry and metallurgy have, however, largely displaced the cruder process with more efficient and economical methods where railroad or truck transportation is available.

Contributed by Stuart Croasdale, Ph.D., Member, American Institute of Mining and Metallurgical Engineers, Denver, Colorado.

BRASS

An Old Alloy That Every Now and Then Is Being Rediscovered as a Great Servant of Mankind

WILLIAM G. SCHNEIDER

Copper was first produced from ores probably 5000 years before the Christian era. About this time bronze became known, not by melting copper and tin together, but rather because the ores available contained tin, nickel and small amounts of other metals and produced alloys harder and stronger than copper. The Bible mentions Tubal Cain as a worker in brass and refers to the alloy in several places. There is reason to believe that not brass but bronze is intended. In the first century Dioscorides makes the earliest unmistakable reference to brass (an alloy of copper and zinc); nevertheless, it was known to the Far East long

before. Due to confusion in names no approximation of a definite time when brass came into use is possible.

Crucible furnaces were used for brass from the earliest times. Calamine (a zinc ore) was the primitive source of zinc. This practice continued to the eighteenth century, when metallic zinc was employed. No further great changes occurred until about ten years ago, when the electric furnace largely replaced the crucible furnace.

Brass was produced in the American Colonies first at the iron foundry of John Winthrop, Jr., Lynn, Massachusetts, in 1644. Cast brass was produced at Philadelphia also previous to the Revolution. The brass business developed from the manufacture of buttons. At Waterbury, Connecticut, in 1750, John Allen established a brass factory and in 1802 scrap copper and zinc from England were fused together and cast into ingots, subsequently rolled into brass sheets and used for buttons. From this humble start the brass industry of the United States, transplanted almost bodily from England, with the exception of brass spinning, has grown to be the greatest in the world. Connecticut now produces 60 per cent of the world's brass.

As production of sheets, rods, wire and tubes increased, the use of brass was extended to other than button purposes. The attractive finish that may be given it, its strength, easy workability and rust resistance so encouraged possible users that consumption of copper by brass mills grew from less than 50 tons in 1820 to over 300,000 tons a century later.

Short brass pipes were used by the Romans as water-measuring devices. The copper pipes of ancient Egypt, however, are the forerunners of modern plumbing pipes. A piece of copper pipe in excellent condition, in the National

Museum at Berlin, believed by Egyptologists to be over 5400 years old, unearthed several years ago at Ghizeh, near the tomb of King Sahoure undoubtedly was used to convey water to his palace and that of his successors. Between copper pipe in Egypt and brass pipe of today are many devious steps,—open troughs of stone and of wood, lead pipe, wooden pipe, iron pipe, steel pipe, tin pipe, concrete pipe. In 1838 the process of producing seamless brass tubing was invented in England and in 1850 was introduced in this country; it is giving fresh impetus to the brass industry.

Brass spinning invented by Hiram W. Hayden, of Waterbury, in 1851, was the first real forward step contributed by America. It quickly replaced the tedious method of producing cupped articles such as vases, pails, pots, other containers and many ornamental objects, by which a disc of metal was hand-hammered and otherwise worked until the desired shape was obtained. In spinning, the disc is mounted in a chuck, which is rotated at the proper speed. By holding suitable tools against the revolving metal it is thinned out over wooden or metal forms to the intended shape.

Hayden's first spinning was done at Wolcottville, now Torrington, Connecticut. According to two daughters who survive him, he invented as a pastime. Among his inventions were a process for color photography and a rifle, displaying wide diversity. He invented many things, but he kept no records. Just what experience or observation or line of thought suggested the method called spinning cannot now be ascertained. One of the largest uses for brass in his day was the manufacture of kettles and pails, originally cast and later hand-hammered from discs. The success of the hand-hammered kettle was short, because the first kettles

so produced were manufactured from the wrong alloy and were unsatisfactory.

Brass pails made by methods in use in 1850 had thin bottoms. To overcome this fault Hayden devised the spinning process. He marked all of his pails as soon as he began manufacturing them by this method. Miss Hayden still has in her home one of the first pails produced by her father in 1851, bearing the date and his name. Hayden also used his process at one time in Waterbury for manufacturing lamps. It was in December 1851 that Hayden brought out the spinning process. In 1852 he sold it to the Waterbury Brass Company. Use of the process has grown so that it may be said to be universal today.

The world is again discovering copper and brass for a great variety of uses and may be said to be entering, on a grander scale, a second Bronze Age, using copper and its alloys much more extensively.

Contributed by Wm. G. Schneider, Member, American Institute of Mining and Metallurgical Engineers, Mining and Metallurgical Society of America, American Electrochemical Society, Research Department, Copper and Brass Research Association.

BOILING AND ROASTING ORES

Further Uses of Salt in Metallurgy of Silver

STUART CROASDALE

Spain for three centuries took great wealth in silver from her American possessions. In 1590, a Spanish priest, Alvaro Alonzo Barba, living at Tarabuco, twenty-four miles

from La Plata, in that part of Peru which is now Bolivia, invented the caldron process for separating silver from its ores. This process was developed particularly for rich surface ores of that district, containing considerable chloride of silver; it was also applied to sulphide ores. It is the ancestor of pan amalgamation, used extensively in the United States during its early silver mining, about two generations ago, and as late as 1913.

Barba's process consisted in mixing pulverized ore with water, salt and mercury, heating the mixture to boiling in a copper kettle, or a vessel with a copper bottom, and stirring constantly. In the treatment of the ore for which the process was invented, the copper kettle took the chemical part of the bluestone used in earlier amalgamation processes.

After chemical action was completed, the caldron was emptied into another vessel, where the gangue was washed from the mercury and the silver recovered from the amalgam as described in Narrative No. 108. Meanwhile, a new charge was boiling in the caldron. The capacity of a plant was necessarily small, but the idea became popular and the process was adopted in Europe in modified form as "barrel amalgamation," in which amalgamating was done in revolving barrels.

"Pan amalgamation" seems to have been an American development, first operated at Washoe, Nevada, in 1861 and long known as the "Washoe Process." The "pan," or caldron, was made wholly of cast iron, or with wooden sides and a hollow cast-iron bottom for introducing steam to heat the ore. Cast-iron mullers for grinding, stirring, and amalgamating were attached to a vertical shaft in the center

of each pan and revolved by steam power. Crushing was done before placing in the pan.

Cast iron replaced copper in the pan or caldron on account of cheapness; consequently bluestone was restored to the ore charge to meet metallurgical requirements. The capacity of each pan averaged about one and one-half tons of ore at a charge and treatment lasted two to three hours. Later the process was made continuous.

As the mining industry aged, easily treated surface ores gave way to refractory ores, with deeper mining. Mining districts were made more accessible, and accessibility permitted use of complicated metallurgical processes, with more elaborate equipment. Refractory ores spurred metallurgists and chloridizing roasting was introduced.

For silver ores it was first conducted in Vienna by Born and then combined with the caldron process at Chemnitz, Hungary, in 1786. The caldron process was soon superseded by barrel amalgamation, first installed on a large scale in 1790 at Halsbrucker Hutte, near Freiberg, Saxony. Metallurgical works had been operated here since 1710 and chloridizing roasting with barrel amalgamation was used not only on lower-grade ores, but also on mattes and other products of smelting furnaces.

For chloridizing roasting, finely ground ore was mixed with salt and roasted in a furnace; the sulphur in the ore was oxidized and formed the sulphuric acid radical* to liberate chlorine from the salt and convert the silver into the chloride. Once converted into chloride, the metal was recovered by

* A radical is a group of different atoms acting in a compound like a single chemical element.

barrel amalgamation or pan amalgamation, or, as the art of metallurgy developed, roasted ore was leached with solutions that would dissolve out the silver chloride. In leaching, roasted crushed ore is subjected to the action of a liquid which dissolves practically all compounds of the desired metal, leaving the gangue, or waste, rocky portions.

From solutions produced by leaching, silver was precipitated in metallic or other concentrated form and melted into bullion. These solvent solutions were brine (common salt), hyposulphite (used in photography), or cyanide of potassium. Brine leaching, first used at the Gottesbelchnung Hutte near Mansfield, Germany, in 1843, was known as the Augustin Process.

Hyposulphite leaching was first suggested by Dr. John Percy, of London, in 1848, but was not applied to ores until 1856, when Von Patera used it on rich silver ores of Joachimsthal District, Bohemia. The Patera Process was first introduced on the American continent by Ottokar Hoffman in 1868 at La Dura, Sonora, Mexico. The cyanide process for treatment of gold ores, proposed by MacArthur and Forrest, of England, in 1890, was first used in the Transvaal. Its use on chloridized silver ores came much later.

Brine gave place to hyposulphite for a number of years, but now hyposulphite is little used and brine leaching is again becoming important not only for treatment of silver ores but for lead ores also; it even threatens to supplant the time-honored smelting process.

Cyanide is more generally applied to raw gold and silver ores without roasting with salt.

Always the object has been to obtain more nearly all valuable metal combined in the ore, at lower unit cost.

Therefore endeavors to improve metallurgical processes continue through research and development.

Contributed by Stuart Croasdale, Ph.D., Member, American Institute of Mining and Metallurgical Engineers, Denver, Colorado.

LABOR SAVING IN TUNNELING

Mucking Machines and Drill Cars

D. W. BRUNTON

American distaste for back-breaking labor has led to many inventions. Tunneling for centuries was laborious, dangerous, uninviting. Only crudest methods and tools were employed until power drills and explosives were used in rock, and power-driven shields in soft ground. Explosives have been made safer and more powerful.

Compressed air has been introduced to exclude water which would otherwise come in through the interstices of the ground. Metal and masonry tunnel linings have been improved and machinery invented for placing them. With engines and boilers came steam drills, then drills driven by compressed air, and finally electric drills. Compressed air drills, however, do most of the tunneling today.

Tunnels are now ventilated by power-driven fans and blowers. Electricity has made good lighting possible. Electric and compressed-air locomotives have supplanted the patient mule and the push-man. Surveying instruments and methods, too, have advanced remarkably. Tunnels can now be driven for long distances from portals or shafts, on

straight lines or curves, or with angles, and the "headings" will meet exactly.

Consequently, tunneling has become much more expeditious and economical, making feasible great improvements in alinement and grade of railways, highways and aqueducts. For great waterway crossings, tunnels have been preferred to bridges.*

In rock tunneling, holes 2 to 3 inches in diameter are first drilled in suitable number and directions then, in proper sequence, loaded with explosives and "shot." The rock is broken out and thrown in a pile of fragments and dust just where the drillers must stand to begin the next "round."

Drills, although much lighter than a few years ago, still are heavy. They have to be mounted on heavy steel columns, bars, or tripods. After the holes have been drilled, the machines have to be dragged out of range of damage. Then as soon as enough of the "muck" has been cleared away, the drilling equipment has to be lugged back over the muck and set up—back-breaking work, falling upon the drillers. It has been difficult to get and keep good men. Intelligent Americans avoid such work. Mucking is hard work, too. The smaller debris is shoveled by hand and the larger chunks lifted by men into small cars.

Rising wages, scarcity of men, and high labor "turnover" made more and more urgent the demands for power equipment. But difficulties in perfecting machine "muckers" were great—nature of the material, limited space and condi-

* See Research Narratives Numbers 31 and 59; also "Mechanical Underground Loading in Metal Mines" by C. E. Van Barneveld, U. S. Bureau of Mines: published by School of Mines and Metallurgy, University of Missouri, Rola, Missouri, 1924.

tions peculiar to underground operations. Nevertheless, progress has been gained by experience and partial failures.

On the Moffat tunnels driven through James Peak of the Rocky Mountains, near Denver, for railroad and water supply, the engineers took advantage of all recent advances and went a few steps further. A practical and efficient mucking machine has been developed and installed and great improvements made in methods of drilling.

The rate at which broken rock at a heading could be loaded into cars has heretofore been the limiting factor in tunneling. Where speed was desirable and hand mucking was employed, it was common practice to level the top of the muck, mount the drills on a crossbar and drill the holes in the upper half of the face while standing on the muck. By the time this was done, the muck would be so nearly cleared that the drills could be taken down and the remaining muck thrown back so that drilling could be begun on the lower half, either by lowering the crossbar or putting up columns.

With mechanical muckers reducing at least 60 per cent the time to clear the muck, when the drills were ready to begin operation, the mucking machine would be removing the muck on which the drillers were standing. Therefore, it was economy not to begin drilling until the muck was entirely cleared, when it was possible to lay track up to the face and thus avoid carrying the drills into the heading and setting them up by hand. The drills are now permanently mounted on a heavy car, which also carries the manifold air and water pipes for each drill, and can be pushed into the face by an electric locomotive, clamped into position and drilling commenced in from fifteen to eighteen minutes.

This, however, is not the sum total of advantages. Under

the old system the drillers were usually tired before they began drilling. Under the new system the men begin drilling while they are still fresh, take greater interest in that work and make better speed.

While men had to do such back-breaking work, when they accumulated a few hundred dollars, they quit the job. With introduction of mucking machine and drill car the men were no longer forced to do hard manual labor, but had merely to look after and operate machines. To most men, especially Americans, this is a congenial occupation.

Hence, "turnover" has almost disappeared. As the men remain for longer periods, they become more expert. The net result has been greatly to cheapen and expedite the work. Thus has a new invention improved a whole chain of interlocking operations in tunneling through rock.

From information contributed by D. W. Brunton, Member, American Institute of Mining and Metallurgical Engineers, Consulting Engineer, Moffat Tunnel.

QUARTZ-GALLIUM THERMOMETERS

Laboratory Curiosities of Yesterday Become Commercial Products of Today

SYLVESTER BOYER

Small pieces of aluminum and other metals now commonly known were once displayed as laboratory curiosities. Chemists had been able to extract them from their ores by laborious processes, but they had no commercial applications. Not

alone was the cost of production high, but the properties of these metals were practically unknown.

Scientists did not stop with discovery, but continued their researches until they became familiar with the properties of these metals. It was then merely a matter of time before commercial applications were developed and cheaper methods of production introduced.

A number of metals now in common use were little known in practical work even a half-century ago, among them aluminum, magnesium, molybdenum, manganese, palladium, iridium, osmium, vanadium and tungsten. Cobalt, nickel, antimony, bismuth, tantalum and certain other metals were known only in a limited way. Silicon, so abundant in the rocks of the earth, was practically unknown until produced at Niagara by the electric furnace twenty-five or thirty years ago.

Other little known elements are coming into use gradually on account of special properties which have possibilities. New uses are being found for even rare elements, either as the pure metals or in alloys oftentimes possessing unexpected and remarkable properties.

Magnesium, first known commercially fifty or more years ago, was an expensive metal. Produced in the form of thin ribbon, it was burned as a source of intense light, particularly for photography at night. It is now readily separated from its ore and introduced into alloys, which, though light, are strong.

Silicon, admixed with steel in the form of ferro-silicon, gave silicon steel, with new properties, and especially assisted greatly in producing cores for electrical transformers. Tungsten, hardly known at all a generation ago except as a black

metallic powder, was ultimately produced as a consistent metal and drawn into wire by the Coolidge process, after remarkably persistent and ingenious research. It is now the basic factor in the highly efficient incandescent lamps of today.

Although clear fused quartz has been known in small quantities for at least thirty years, production of high-grade clear fused quartz in large quantities was an achievement of the Thomson Research Laboratory of the General Electric Company at Lynn, Massachusetts, only a few years ago. It is remarkably transparent and but little affected by temperatures at which most metals melt.

Gallium was discovered by a French scientist, Lecoq de Boisbaudran, in 1875, and derived its name from Gallia, the Latin for France. But little further work was done with the element. The existence of such a chemical element had been predicted several years before. Its characteristic lines were observed by the discoverer while examining the spectrum of a piece of zinc blende.

Known for 50 years as a rare metal, it never had any commercial use until Sylvester Boyer, in the Thomson Research Laboratory, recently produced the gallium thermometer for the measurement of higher temperatures than can be measured with mercury-and-glass thermometers.

Gallium, when liquid, is similar to mercury in appearance, but is less than half as heavy. It melts at about 86 degrees Fahrenheit but often may be cooled to more than 8 degrees below zero, before becoming solid. It does not boil (give off vapor) under 2700 degrees Fahrenheit, its boiling point being estimated at between 1500 and 2000 degrees Centigrade, equivalent to about 2700 to 3600 degrees Fahrenheit.

Because of certain impurities the liquid metal formerly wetted glass and quartz, and therefore was unsuitable for thermometers. It was first made suitable for thermometer use by the recent work of Boyer. Quantities of the metal can now be prepared for whatever uses may be developed.

By utilizing the properties just mentioned of these two materials a convenient new high-temperature thermometer became practicable. The quartz-gallium thermometer differs little in appearance from the ordinary mercury thermometer. It could not be made sooner because the two substances, although known, were commercially unavailable.

In the United States a source of gallium was discovered ten years ago in the "leady residues" left after the distillation of zinc from certain ores. Residues from such ores in Missouri and Oklahoma contain considerable gallium; but since there were no commercial uses for gallium, these residues were sold only for the lead in them.

Science is conquering slowly or rapidly, as you prefer to look at it. Compared with ancient times, its conquests now proceed at express speed. From the standpoint of desirable progress, the speed is slower than we would like to have it. From time to time the missing chemical elements in the predicted list are being found. Only two or three of the elements which form the whole material universe remain undiscovered on the earth. Most of the 92 elements have been put to use by Man.

Based on information furnished by Sylvester Boyer, Thomson Research Laboratory, General Electric Company, Lynn, Massachusetts.

CHLORIDIZATION AND VOLATILIZATION

Two Recent Methods of Reducing Non-Ferrous Ores With the Aid of Chlorine

STUART CROASDALE

Roasting silver ores with common salt (sodium chloride) paved the way for two entirely new processes, first, the recovery of base metals (copper, zinc and lead) after chloridization (roasting with chlorine in the form of salt), and second, the volatilization process. Formerly, no effort was ever made to recover base metals from chloridized ore, except to get them out of the way. They were usually considered detrimental in the recovery of silver, although their value as chloridizing agents was early recognized.

In 1844, Longmaid, of England, obtained a patent for treatment of copper ores by chloridizing roasting and brine leaching, but it was not until 1860 that the process was commercially applied by William Henderson, of Scotland, to pyritic residues from acid-making for recovery of copper. The process is still used extensively and is another example of the birth of a valuable invention a generation before its merit was recognized.

In recent years the same process has been applied to low-grade silicious lead ores and also to low-grade complex ores for separation of lead, copper and silver from zinc. Brine leaching, with the solution acidified with acid or chlorine, has been used in the treatment of certain raw ores of this character. In the complete cycle, high-grade zinc chloride is made and sold for the preservation of timber, particularly railroad ties.

Loss of metals from volatilization during chloridizing roasting was already known when Plattner published his "Metallurgische Rostprozesse" in 1856. He mentioned considerable loss of silver chloride when it came in contact with other easily volatilized chlorides and discussed at length the volatile products of chloridizing roasting, but he failed to record any loss of gold by volatilization.

C. H. Aaron, of California, was probably the first to recognize chlorine as the cause of serious losses of gold by volatilization when an ore is roasted with salt; he published the results of his work in 1881. Not until 1891–93 did Stuart Croasdale, at Aspen, Colorado, discover that a commercially complete (above 90 per cent) volatilization of gold could be obtained from Cripple Creek ores by roasting with salt.

About the same time Edwin C. Pohle, of Denver, Colorado, obtained similar results on silver ores. Later investigations by these men demonstrated that not only gold and silver, but also lead, copper and other metals could be commercially volatilized and so completely removed from the ore during the roasting operation that the waste could be sent to the dump without further treatment.

These metals are volatilized as chlorides and can now be recovered by electrostatic precipatators as a highly concentrated fume, from which they can be separated in metallic condition. It is possible, with this process, to separate these metals from zinc in complex ores. Under proper regulation, zinc does not volatilize during the chloridizing roast.

Anhydrous aluminum chloride for "cracking" petroleum can be made by the volatilization process. This process is also adapted to the treatment of a number of the less

valuable ores. Like many important inventions, it was born before its time and was developed about fifteen years before the physical chemistry governing its operation was known.

Plattner was first to propose chlorine gas for treatment of gold ores; this process was put into commercial application in Silesia, Germany, in 1851. Ore was roasted free from sulphur and then treated with moist chlorine gas and leached with water. The gold dissolved and was recovered from solution as a metallic precipitate, which was melted into bullion. This process was extensively used in the United States for treatment of gold ores, but was gradually replaced by the cyanide process. The last chlorination plant went out of existence about 1918.

Dry chlorine gas is a very active reagent for attacking sulphide ores and was first proposed for treatment of complex zinc-lead ores by Swinbourne and Ashcroft, of England, in 1897. After much experimentation, the process is now ready to be commercially applied. All metals associated in the non-ferrous ores under consideration may be recovered in metallic form, or the process may be used for making zinc chloride directly from the ore, and the lead sludge may be shipped to smelters.

Chlorine gas is used exclusively in detinning processes, for making aluminum chloride and in other minor metallurgical processes. It can be made on the ground or can be bought in tank cars as a by-product from certain chemical industries. Since the World War the chlorine capacity of the United States has been far in excess of demand.

Chlorine in metallurgy reached its zenith in the early nineties. When the United States adopted the gold standard in 1893, the price of silver dropped and silver became a by-

product of the smelting industry. The few strictly silver mines that continued to operate changed to the cyanide process, which by that time had been adapted to silver ores.

Gold ores are universally treated by the cyanide process. Within the last decade, however, common salt and chlorine have become increasingly important in complex ore metallurgy, as well as in the metallurgy of silver and lead and a number of minor metals.

Contributed by Stuart Croasdale, Ph.D., Member, American Institute of Mining and Metallurgical Engineers, Denver, Colorado. See also Narratives Nos. 108 and 110.

THADDEUS HYATT

An Early American Investigator and User of Reinforced Concrete

CHARLES M. SPOFFORD

Thaddeus Hyatt, one of the first advocates of the use of reinforced concrete, was born in New Jersey in 1816 and was educated as a lawyer. Realizing the increase in property values which would occur from lighting the basement areas under the sidewalks of cities, he early devoted himself to devising and making an illuminating sidewalk grating,—the Hyatt grating, which became extensively used in New York City.

After his business became so well established that he could leave its management to others, he devoted the larger part of his time and considerable money to study and investigation along other lines in which he was interested.

One of the subjects which was foremost in Hyatt's mind was that of the construction of fireproof buildings. In 1877 he published for private circulation a book entitled "An Account of Some Experiments with Portland Cement Concrete Combined with Iron as a Building Material with Reference to Economy of Metal in Construction and for Security against Fire in the Making of Roofs, Floors and Walking Surfaces." This book, copies of which may be found in several of our important engineering libraries, including Engineering Societies Library in New York, gives a detailed account of what was probably the first serious and comprehensive investigation of the properties of reinforced concrete with respect both to strength and resistance to fire.

Hyatt's knowledge of the value of the combination of iron and Portland cement concrete came from his use of these materials in making his sidewalk gratings. The evidence thus gained was apparently sufficient to induce him to embark on the extensive set of experiments described in his book. These experiments were made in London, where Mr. Hyatt spent a good part of his time, by the well-known testing engineer, Kirkaldy.

Included in these experiments were twenty-six concrete beams reinforced in various ways, one beam of plain cement and several of brick and tile laid edgewise with longitudinal reinforcing rods. Various methods of reinforcing were used, including longitudinal tensile and compressive reinforcement, bent up rods and transverse reinforcement. The beams had a span of 5 feet, were 12 inches in width and were from 8 inches to 12 inches deep, thus being of sufficient size to give valuable results.

In addition to the beam tests, experiments were made to

determine the coefficient of expansion and the coefficient of elasticity of concrete, and a fire test was made on a good-sized floor slab. As a result of his studies and tests, Mr. Hyatt drew the following conclusions, all of which, except that listed under (e), are in accordance with present day practice:

"(a) That fireproof construction requires that all iron beams shall be absolutely surrounded by fireproof material.

"(b) That Portland cement concrete is fireproof.

"(c) That the bond between concrete and iron bars or rods is sufficient to develop the strength of the iron, and that such a combination is much more economical than one consisting of concrete and rolled beams.

"(d) That the coefficients of expansion of iron and concrete are practically identical.

"(e) That the ratio between the moduli of elasticity of concrete and wrought iron is about 1 to 20.

"(f) That high concrete chimneys reinforced with metal extending upward and threaded with wire hoops should be lighter, cheaper and stronger than unprotected chimneys.

"(g) That concrete combined with iron may not only be used satisfactorily for buildings, but that this material should also be satisfactory for bridge construction, since such a bridge should be weatherproof, need no paint, and probably cost less for repairs."

Hyatt was so firmly convinced by his investigations of the desirable qualities of reinforced concrete for fireproof building construction, that he not only used it in constructing a building on Farrington Road, London, but actually started a fire in the building to demonstrate its fireproof qualities.

This sketch would be incomplete were no mention made of

the notable activities of Mr. Hyatt against slavery. He was on terms of intimate relationship with John Brown and after the Harper's Ferry incident, was called to Washington to testify, but refusing to do so, was imprisoned for some time in the old Capitol Prison in Washington.

Hyatt's death occurred in 1901, at the age of eighty-five. He lived long enough to see the widespread application of reinforced concrete in the construction of fireproof buildings, bridges and other structures.

Contributed by Charles M. Spofford, Member, American Society of Civil Engineers, of Fay, Spofford & Thorndike, Consulting Engineers, Boston, Massachusetts.

DUCTILE ARC WELDS

An End to Noisy Riveting?

IRVING LANGMUIR

A step forward in the utilization of the heat of electric arcs in the joining of metal parts or the building of metal structures—another step toward the day when the pounding, noisy riveter will resign in favor of the quiet electric welder for most work—has been taken in the development of two methods of producing ductile welds. The one was developed by Dr. Irving Langmuir in the Schenectady Research Laboratory of the General Electric Company; the other almost simultaneously in the Thompson Research Laboratory of the company at Lynn, Massachusetts, by Peter Alexander.

In both processes, while the welding is being done, air is excluded from the metal at the joint by means of a bath of

hydrogen or other suitable gas. The formation of oxides and nitrides which are objectionable, in the weld metal, is thus prevented; the fused metal is as strong and ductile as the original metal.

The development of the Schenectady method is a good example of the unexpected eventual commercial application of experiments in pure scientific research. Fifteen years ago, while studying the loss of heat of the tungsten filaments of incandescent lamps in an atmosphere of hydrogen, Dr. Langmuir found that at a high temperature the hydrogen gas was changed from the molecular to the atomic state. Two atoms are grouped together as a unit in a molecule of hydrogen gas; in the atomic state each atom acts as a unit. The molecular form is the more stable, and when the atoms recombine to form the molecules, intense heat is liberated.

Dr. Langmuir's study of lamp filaments in hydrogen was a theoretical investigation. Now, fifteen years later, the results have been applied in a different field—in the development of a new and improved method of welding.

Continuing the theoretical investigation, Dr. Langmuir found that more atomic hydrogen was formed by passing a powerful electric arc between tungsten electrodes in hydrogen at atmospheric pressure. By directing a jet of hydrogen from a small tube into the arc, atomic hydrogen could be blown out of the arc, forming an intensely hot flame of atomic hydrogen burning to molecular form and liberating about half again as much heat as does the oxy-hydrogen flame.

By using such a flame of atomic hydrogen, iron can be welded or melted without contamination by carbon, oxygen or nitrogen. Because of the powerful reducing action of the

atomic hydrogen, alloys containing chromium, aluminum, silicon or manganese, can be welded without fluxes and without oxidation. The rapidity with which such metals as iron can be melted exceeds that in the oxy-acetylene flame, so that the process promises to be particularly valuable for welding. Either alternating or direct current can be used with this process.

Materials of many kinds have been welded with the atomic hydrogen flame. Low carbon steels up to one-half inch in thickness have been welded without additional material after butting together tightly. Much work has also been done in connection with full automatic welding, using a butt joint, with no metal added to the seam. A number of welds have been made on seamless tubes having a diameter of four inches, and with boiler plate one inch thick. Welds on deoxidized copper, such as silicon-copper, have been made up to three-eighths-inch metal, giving unusually good sections.

In testing welds made by this process, the welded portions have been twisted and bent double without cracking or otherwise being injured. Such results have not been attained with the ordinary arc weld, since such welds are usually brittle because of the presence of nitrides or a thin film of oxide or scale, avoided in the new process by the presence of the hydrogen.

The process developed in the Lynn Laboratory is based on the utilization of the chemical and physical properties of hydrogen and other gases in the molecular state. This process aims primarily at the prevention of the formation of the nitrides and oxides in the arc-deposited metal, which limit the ductility of the usual arc welds.

In this process the arc is struck between the metallic wire

or carbon used as one electrode and the plate or work to be welded used as the other electrode. The crater of the arc is always on the work to be welded. The gaseous atmosphere is supplied in the form of a stream around the arc. Pure hydrogen, water gas, hydrogen-nitrogen mixtures, anhydrous ammonia, methanol vapor and some other gases can be used, according to the nature of the work. The process makes arc welding more efficient, and suitable for fields which at present are out of its reach. Low-carbon steel, alloy steels, and most of the non-ferrous alloys can be welded with success by this process in suitable gaseous mixtures.

Based on information supplied by Dr. Irving Langmuir, General Electric Research Laboratory, Schenectady, New York and Peter Alexander, the Thomson Research Laboratory of the same company, Lynn, Massachusetts.

ELECTROLYTIC IRON

A Metal of Great Purity, Ductility and Malleability

CHARLES P. PERIN

For milleniums, man has used fire for extracting iron from ore. To bring together ores, fluxes, fuels and other supplies at suitable places in quantities to satisfy modern needs necessitates transportation on a prodigious scale. But there are huge deposits of iron ores remote from fuels, yet relatively near regions of large potential demand for iron and steel and not far from waterfalls by which electricity could be generated cheaply. For years scientific men have been trying to produce iron directly from its ores by means of electricity.

There is another problem which concerns us all. Of the iron and steel produced by so great expenditure of energy, 20,000,000 tons are estimated to slip away each year by corrosion. Not only are expensive finished products lost, but the indirect costs are very great for temporary prevention, repairs and replacements. Cannot electricity help in producing at reasonable cost iron which will rust less rapidly or not at all?

Furthermore, discarded iron objects, from cans to automobile bodies, are increasingly disfiguring the countryside, especially in proximity to communities. Could not large tanks of iron solvent, ferrous chloride, for example, be maintained in convenient places, into which these wastes could be dumped? Then the iron could be recovered by electrolysis. Other aspirations also are entertained by forward-looking metallurgists.

Visionary? Generations away? May be not! And "Where there is no vision, the people are perishing." They may not suspect danger, for the early steps of decadence are easy and pleasant.

But how far have the electrolytic iron men progressed? About fifty years ago, iron was produced electrolytically by Elihu Thomson and Edwin Rice but found so hard, rough and brittle that nothing was done with it. Since then many patents have been issued in France, the United States and other countries.

A few years ago, the most successful concerns in France and the United States found that each had knowledge and patents that would be valuable to the other. They combined forces. In America the Niagara Electrolytic Iron Company has rehabilitated a chemical plant recently pur-

chased at Niagara Falls and is commercially producing iron of a purity of 99.96 per cent while continuing research and development. This iron is resistant to corrosion and has advantageous physical qualities.

The process begins with large bars of cast-iron, which as anodes of huge batteries are dissolved in the electrolyte of ferrous chloride. From this solution the current deposits the practically pure iron on the cathodes, which are long, thick, hollow steel cylinders with smooth surfaces. The cathodes are revolved slowly and the electrolyte is kept in constant circulation through the battery cells, or tanks. These cells are of reinforced concrete impregnated with 5 per cent by weight, of sulphur.

On each cathode the electric current builds a seamless tube of iron ordinarily 9½ inches internal diameter and 13 feet long, of any thickness desired, up to ¼ of an inch. Diameter and length of tube can be varied by using cathodes of different sizes. Thickness depends upon time and current. The initial deposit is full of hydrogen, which embrittles the iron. Therefore, the cathode and the adhering tube, upon removal from the battery, are passed through an oil-fired annealing furnace, which removes most of the hydrogen.

For removal from the cathode a special stripping machine is used which enlarges slightly the diameter of the tube by kneading the iron between the cathode and three rolls which are forced against it by hydraulic pressure. Then the tube is further annealed in an electric furnace. The cathode is returned to the battery. The electrolyte is regenerated in special tanks by aid of steel scrap and is used continuously.

By slitting, flattening and rolling, the tubes may be converted into plates of any desired thinness. Or the tubes may

be slit into narrow strips or into coils for drawing into rods and wire.

Seamless tubes for steam boilers, condensers, evaporators and oil-cracking stills may be made to advantage from this iron; also containers for compressed gases, automobile mufflers, paper mill rolls, deep stampings and many other articles for which great purity, malleability, ductility, or resistance to corrosion are desired. And so by patient research, courageously supported by men of faith, the world is being enriched by a new group of industries with great possibilities.

Based on information supplied on request by Charles P. Perin, Member, American Institute of Mining and Metallurgical Engineers; President, Niagara Electrolytic Iron Company, Inc.

INSIDE-FROSTED LAMPS

A Discovery Promoting Efficient Light Production

W. M. SKIFF

Growing appreciation of the importance of good electric lighting during the decade between 1915 and 1925 led to much wider use of diffused light. Diffusion by enclosing the lamps in translucent glassware and adequate shades and by using other devices was a vague subject to the general public.

Consequently with the advent of the high-efficienty tungsten lamp, the manufacturers endeavored to conceal the bright filaments by etching or frosting the bulbs. Frosting on the outside of the bulb proved objectionable for two chief

reasons. It was wasteful of light, offsetting, to a slight degree, the great progress made in increasing the light-producing efficiency of the filament. Also, outside-frosted lamps collected dust and dirt quickly, which could not easily be wiped off.

For many years lamp engineers realized that a lamp frosted on the inside, instead of on the outside, would be very desirable. It would not only present a smooth outside surface and be as easily cleaned as a clear lamp, but a lighter frosting would suffice, increasing the efficiency. The trouble with the idea was, that when a lamp bulb was frosted on the inside, it became as brittle as an egg shell. For twenty years engineers wrestled with this problem to no avail, until Marvin Pipkin, of the National Lamp Works of the General Electric Company, solved the difficulty. The method is simple.

A strong solution of acid is first sprayed into the bulb, which etches it. In this condition the surface of the glass is made up of irregular little projections with many sharp angles. While the glass is still in this state it is extremely weak, and a slight pressure or bump is sufficient to shatter it. So far, the process is similar to former attempts at inside frosting. The difference lies in the strengthening process, which is the application of another acid solution, somewhat weaker than the first. This second treating rounds off the sharp edges and minute projections, giving the glass an appearance, under a powerful microscope, of being made up of tiny hemispheres. The bulb is now strong again,—just as strong as it was originally.

Superiority of the inside-frosted lamp over the outside-frosted, so far as light transmitting characteristics are con-

cerned, also needs explanation. In the outside-frosted lamp, light from the filament travels through the gas or vacuum to the wall of the bulb, then through the glass, on the outer surface of which it meets the frost. Then, depending upon the direction of the plane of the particle of rough surfaces, the beam either passes on through the frosted surface as useful light or is reflected back through the glass layer. Each time the light passes through the glass, a certain amount of absorption takes place.

Diffusion of the light by the inside frost is obtained by prismatic refraction with comparatively little loss. In fact, the inside frost allows an even greater portion of the light to pass through than does a similar frost on the outside of the lamp. This is due to the fact that the multiple internal reflections are not so numerous in the inside-frosted lamp because the rough, interior surface does not reflect any considerable portion of the light back and forth inside the lamp, as happens with the outside-frosted lamp. Moreover, the relative absorption of the inside frost does not increase so rapidly with the life of the lamp as does that of other diffusing media.

For these reasons, then, the inside-frosted lamp is only about two per cent less efficient than a clear lamp, contrasted with a loss of efficiency of three to four times this much in the old style sand-frosted and sprayed lamps.

Another great benefit of the discovery of inside frosting is at once apparent when it is realized that now the manufacturers need only one type of lamp of each wattage instead of lamps with several different finishes. This is beneficial not only from the standpoint of economies resulting from the increased use of automatic machinery and the decreased

investment in lamps lying idle in warehouses and on dealers' shelves, but also there is still greater benefit for the public in general.

Since the inside-frosted lamps give practically as much light as clear lamps, they can be used to replace clear lamps for every ordinary use. This means that wherever, because of ignorance or carelessness, lamps are used without proper shades or glassware, the inside-frosted lamps will afford a certain degree of eyesight protection. Furthermore, wherever lamps are properly shaded, the inside-frosting will eliminate sharp shadows and striations, with negligible loss of efficiency.

The invention of the inside-frosting process, of the same order of importance as the invention of gas-filled lamps and tipless lamp construction, is one more example of the value of systematic research, persistently pursued.

Contributed by W. M. Skiff, Member, American Institute of Electrical Engineers, National Lamp Works, of General Electric Company, Cleveland, Ohio.

GRINDING

A Precision Method for Quantity Production

ALDUS C. HIGGINS

"Grinding," like many another English word, has more than one signification. To the miller it means making flour of grain. To power and metallurgical engineers it means reducing coal or ore to powder as a step in a process. To machinists it meant not so many years ago giving metal

parts a refined finish by removing a little surface metal with a small thin abrasive wheel in a light machine.

In 1886, Charles H. Norton, born at Plainville, Connecticut, in 1851, began putting a new meaning into "grinding." Progress was slow. In 1895, Niagara, harnessed, began to supply electric current in unprecedented quantity at low price. About this time, Charles B. Jacobs invented a new abrasive, known by the trademark "Alundum." Soon Aldus C. Higgins followed with the water-cooled electric furnace for producing alundum abrasive in quantity, in the works of a company bearing the name of a Norton of another tribe. Norton, C. H., now had a strong, effective cutting medium for his grinding machines.

Norton was trained at the Seth Thomas Clock Works in making machines for indicating the passage of time. He was impressed deeply with the value and the never failing exactness of time. Later, he noted the great amount of time and highly paid labor then required for precision grinding.

Realizing more and more the usefulness of precision grinding in modern machine production, he set out to reduce its cost. About that time, new special steels were making feasible very deep cuts with metal-working tools and were absorbing interest generally. Norton, however, appears to have been first to perceive that the electric furnace abrasive wheel, mounted in a heavy machine, might remove metal in small particles as rapidly as the special-steel cutting tools. This conception started him on his experimentation.

At first, "practical" machinists thought Norton's ideas very impractical. Fortunately, however, there were enough courage and money to back his investigations and demonstrations. During the past two decades, a remarkable

ALDUS C. HIGGINS

evolution has been wrought, a new mechanical process has been brought into wide use.

Twenty-five years ago the grinding machine was a light, low-powered tool, polishing surfaces and occasionally doing accurate sizing to a limit of one-thousandth of an inch, at great cost. Today, a heavy, high-powered production tool with a precision of one four-thousandth of an inch in commercial manufacturing, it has become a big factor in low-cost and high-rate production of automobiles, locomotives, machine tools, cash registers, linotypes, monotypes, adding machines, typewriters, agricultural machinery, machine tools, armament and many other metal objects.

Norton's fundamental idea was that a modern abrasive wheel set in a sturdy machine and driven by a lot of power could cut metal rapidly, accurately and cheaply in spite of high first cost for equipment. Old grinding machines used a fraction of a horse-power. He proposed applying at least 15 horse-power in each machine. The old wheels removed about one-sixteenth of a cubic inch of metal per minute. Grinding machines now remove from two to six cubic inches and in rare operations as much as twelve cubic inches each minute.

Frequently, when cutting as much as three to four cubic inches of metal in a minute, grinding machines leave the work sufficiently accurate and well finished to need no further refinement. From being a method of securing refinement at great cost, grinding has become one of the cheapest methods of production for cylindrical objects of metal with finished surfaces. Flat surfaces also can be produced very accurately.

Novel features were introduced for getting great accuracy

without the highly skilled machinist. Mechanics of ordinary training can obtain the desired results. Modern quantity production demands interchangeability of parts. Each part must be made so accurately as to size and shape that any of them can be used without selection in putting the mechanisms together. The new grinding machines made it possible to secure exact size on repetitive work in unlimited quantities.

The old conception of precision and delicate adjustment was embodied in light, small, beautifully made mechanisms. Norton made massive machines with heavy operating parts capable of being moved a distance so small that a line of that width could not be seen with the naked eye. That the movement can be made repeatedly with absolute dependability has often been proved by making four adjustments of twenty-five one-hundred-thousandths of an inch, always arriving exactly on the test line. The paper on which this Narrative is printed is about five one-thousandths of an inch thick. Imagine it split twenty times and you will get some conception of the precision with which these modern grinding machines can cut metal.

By combining massiveness and large power with great precision and utilizing the superior new abrasives, Norton developed a new art of cutting metal which has contributed largely to present-day economy and efficiency of many machines in daily use on farm, highway and railroad, and in factory, office and home.

Contributed on request by Aldus C. Higgins, Member, American Society of Mechanical Engineers; Treasurer, Norton Company, Worcester, Massachusetts.

A MONEY MAKING PROCESS

A New Use for Chromium, the Hardest of Metals

WILLIAM BLUM

The U. S. Bureau of Engraving and Printing has a monopoly in this country on the printing of paper currency and U. S. Government securities, and is very zealous to maintain it! One of the best ways to render counterfeiting more difficult, is to have all genuine bills of a given design absolutely identical. Any defect observed in a single line or dot is then an indication of counterfeiting.

To produce perfect impressions, the plate printing process is employed. The designs on the plates are "intaglio," i.e., they are below the plane surface of the plate. In printing, the entire surface is coated with ink; the excess is carefully removed by wiping, leaving the ink only in the lines. When the paper is then pressed upon the plate, the ink is picked up, giving sharply defined lines in the print.

There is considerable abrasion from the particles of pigment in the inks; plates even with a case-hardened steel surface, usually yield only 30,000 to 70,000 impressions. All plates used, until a few years ago, were of steel; they were produced by "transfer." In this process the design is rolled into a soft steel plate, which is then case-hardened. There are only a limited number of "transferrers" or "siderographers" in this country.

It was therefore very difficult during and just after the war, to meet the demands for Liberty Bonds and for an increased supply of paper currency. Demand for currency has continued to increase; more bills are needed to pay increased prices of merchandise; money is deteriorated more rapidly by the soiled hands of gasoline filling-station em-

ployees. Other methods of reproducing the printing plates were therefore investigated.

Very faithful reproductions of engravings can be made by electro-deposition, but such plates as are made in electrotyping, or even plates consisting of a nickel surface, followed by copper deposited to a thickness of a quarter inch, would not withstand the pressures used in plate printing.

At the Bureau of Engraving and Printing it was discovered that by depositing alternate layers of nickel and copper, a plate with the necessary strength could be produced. This principle was employed in the electrolytic plant designed in 1920 by the staff of the Bureau of Standards, which has since been in successful operation at the Bureau of Engraving and Printing.

Electrolytic plates are made more cheaply than steel plates and yield very fine impressions. Even with the hardest nickel surface that could be produced by deposition, they did not last as long as the case-hardened steel plates; so it was desirable to produce a harder surface.

A study was then conducted at the Bureau of Standards, chiefly by H. E. Haring, upon the possibility of applying chromium to these plates. It was then known that chromium was very hard and subsequent tests have shown that, as measured by the width of a scratch produced when a diamond or a sapphire is drawn across it, it is the hardest metal thus far examined.

Although the deposition of chromium was reported in 1854 by Bunsen, and numerous papers have been published on this subject, no extensive practical applications of chromium plating had been made in this country up to 1924. Haring's work showed that to obtain bright hard deposits, such as would be suitable on a printing surface, the condi-

tions of plating must be carefully controlled, especially the acidity and temperature of the solution and the density of the electrical current.

As a result of this study, the process was installed at the Bureau of Engraving and Printing, and has been eminently successful. The impressions are somewhat sharper than from the nickel or steel plates. A layer of chromium only two ten-thousandths of an inch thick deposited upon the nickel surface of an electrolytic printing plate increases its useful life to at least four times that of a nickel surface, and twice that of a case-hardened steel surface.

As fewer plates are required, the currency is even more nearly uniform then formerly. The method is therefore in a double sense a "money making process."

Chromium is now attracting the attention of many manufacturers. Its possibilities lie in (1) its great hardness and hence its suitability for printing plates, dies, gages, cams and gears, (2) its high luster and resistance to tarnish, which render it useful for exposed reflectors, and (3) its resistance to atmospheric corrosion, which has led to its application, usually over nickel plating, on automobile radiator shells, bumper bars, plumbing fixtures and other objects.

Through the studies of chromium plating now in progress at the Bureau of Standards and in numerous commercial research laboratories it seems certain that within a few years it will become common-place, instead of being a chemical curiosity.

Contributed by William Blum, Chief of Electro-chemistry Section, U. S. Bureau of Standards.

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PHOTO-ELECTRICITY

Current Generated by Light

HERBERT E. IVES

Faraday's investigations on electromagnetism are striking examples of small beginnings. Another is the work of Heinrich Hertz. Within a few years he laid the foundations of modern radio, probably the greatest practical triumph of Maxwell's electromagnetic theory of light, and discovered the photoelectric effect, not yet of comparable practical importance, but exemplifying the inadequacy of that same theory.

Hertz produced electromagnetic waves by causing sparks to pass between separated metal electrodes in air. In 1887, he observed curious irregularities. With all electrical conditions the same the sparks would sometimes pass easily, at other times not at all. This behavior excited his curiosity; he sought for its cause, and discovered that when light was falling on the electrodes the sparks passed most easily. Ultra-violet light, such as the light from another spark, was most effective, as shown by great decrease in influence when a clear plate of glass was interposed.

Other experimenters soon found that the effect of light on a metal electrode was to make it acquire a positive charge, or lose a negative charge. Later, after J. J. Thomson had discovered the electron, it became clear that when a metal is illuminated it gives off electrons.

Lenard, pupil of Hertz, who first systematically studied photoelectric effect, found a peculiar characteristic of the emitted electrons, which has kept the greatest minds in physics guessing: the number of electrons emitted was pro-

portional to intensity of illumination, as one would expect; but the energy with which they were emitted was quite independent of the intensity of the light, depending merely on its frequency, or color.

Thus, whether we get our light from an arc lamp a foot away, or from a candle a mile away, or from a star ten light years away, the electrons shoot out from the illuminated surface with the same initial energy—that is, the metal plate must be charged to the same positive potential to prevent their escape.

Sir William Bragg has pictured the phenomenon as follows: Suppose a plank dropped from a ship at sea. Waves would spread outward, ever diminishing in height; another ship would intercept a minute section of the wave front; instantly a plank would be exploded from the side of this ship, and fly to the height from which the original plank fell.

To explain this extraordinary effect, Einstein formulated his first revolutionary physical theory, of *light quanta;* light consists not of electromagnetic waves in the ether of uniform intensity along their whole fronts, but of bundles of energy; the wave front is "speckled." This quantum is the same quantum of energy turning up whenever radiation and matter interact.

No doubt of its reality, and of its importance in the explanation of the physical universe, although apparently irreconcilable with the wave theory supported by all the phenomena of interference and diffraction. Electromagnetic waves from Hertz's spark gaps wonderfully confirm the wave theory, while their light produces photoelectrons which act contradictorily.

Practical applications center around the development of

highly sensitive photoelectric cells. Metals differ in power of emitting electrons under illumination. Best conditions are obtained by putting the metal in a glass or quartz enclosure, and controlling both the kind of atmosphere and its pressure.

The more electro-positive the metal, the more photosensitive; so in place of zinc and copper, used in the earlier studies, an alkali metal, potassium, rubidium or caesium, is used in non-reacting atmospheres—an inert gas, argon, helium, or neon—at a low pressure suitable for multiplying the photo-current by the electric conduction induced in the gas by collision of the electrons with the gas atoms.

The typical photoelectric cell is a glass bulb, with one electrode, the cathode, usually a layer of alkali metal on the inner surface, with a wire leading out through the glass, and another electrode, the anode, a loop of wire, likewise carried out. Connect these two wires through a galvanometer and let light shine into the bulb; the galvanometer will show an electric current flowing. The current starts and stops instantaneously; it is proportional to the illumination. It is quite small, but with proper instruments it may be used to measure the intensity of light from such faint objects as sixth magnitude stars.

In electrical transmission of pictures* photoelectric cells do exactly what is required. They transform the light and shade of a picture, as traced by a tiny beam of light, into an electric current, varying exactly with the picture values, and without lag or distortion. To be used, some means had to be found to increase the minute photoelectric currents for transmission over telephone or other lines. This has in

* See Research Narratives 33 and 107.

recent years been made possible by development of the thermionic vacuum tube.*

May we look to photoelectricity for direct conversion of the sun's radiation into electrical energy, for industrial purposes? As yet efficiency is so low as to offer no immediate promise. It is probable that utilization of the sun's radiated energy by vegetation is primarily induced by photoelectric response. We may, by advancement of knowledge of photoelectricity, master ultimately the utilization of solar radiation, though we may have to resort to the indirect method of nature.

Contributed by Herbert E. Ives, Ph.D., Bell Telephone Laboratories, Inc., New York.

THE GYRO'S STRANGE INTUITIONS

ELMER A. SPERRY

Unique and even wonderful are certain characteristics of the gyroscope. Suppose we had a circle with one chair occupied by a gyroscope instead of mere man, and imagine he could speak to us. Let me tell you some of the interesting things that he would pipe up and say:

"I know things that none of you mortals are in the least aware of. For example, I know that this chair in which I sit is moving, I can feel its direction and tell you its velocity. I am sure none of you has any intuitive sense of these things, but I know them instinctively. It is also easy for me to discern the difference between unilinear motion and circular motion, or motion around a center, no matter how remote

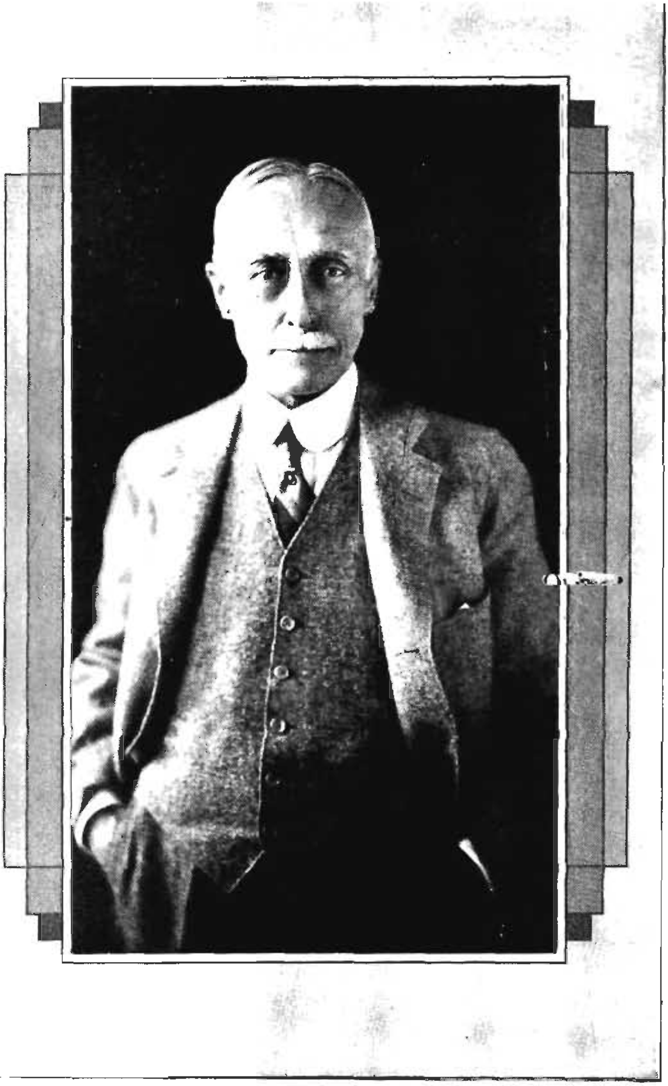
* See Research Narratives 33 and 107.

or distant this center may be. As a matter of fact, this motion that I feel is around a very remote center—some 4,000 miles away—and if you stop to think, this involves an axis of motion. The exact direction in which this axis lies with reference to this city, this room, and even the chair in which I sit, is quite apparent to me."

The astonished circle look at each other and cannot refrain from commenting that such information is not only remarkable, but might become extremely useful. It would be of the utmost usefulness to the mariner if we could make the little gyro articulate in terms that could be universally understood, because if we only knew with a high degree of precision exactly the direction of the axis of the earth, this would at once give the precise direction of all meridians. If our point be moving, as a ship either in the water or in the air, this information could give us the exact position of our meridian at all times and places.

So it has been one of the objects of the last thirty years of my life to make the gyro articulate and to check up on him rather critically, (1) as to the exact degree of his precision, (2) as to his being perfectly understood, and (3) to safeguard him against disturbances due to the various and sometimes violent motions of his mount. This has gone forward until the time has come when the great value of such a safeguard to accurate navigation, especially under conditions where observations are impossible, has become more and more understood.

It is comforting to know that as our little gyro goes humming on his way, this precision orientation which through his sixth sense he so freely and cheerfully dispenses, is based on a definite "field" that he employs as his energizing force,



ELMER A. SPERRY

which is all pervasive and never failing. There is no place on the earth that does not revolve and there is no place where he does not feel the urge to service, except possibly at or near the actual pole on the ice cap, where he shakes his head and says, "What is the use of pointing to any one meridian, for here they all are, together with the pole itself."

If anyone challenges his accuracy or value, there are some 2,000 of his brothers distributed in over one hundred fleets, largely merchant marine, that will stoutly enter instant and convincing proof, and if one wishes to push investigation still further and comprehend the marvelous training that he has received through long aeons, coming down through the centuries with his intuitions tuned to the nth degree, I have only to call attention to the wonderful sensitiveness of his response to influences that are really infinitesimal.

The precession velocity of gyros varies. Quite large stabilizing gyros for ships precess at measurably one radian; other services often require many radians. One recently manufactured for the testing laboratories of the Massachusetts Institute of Technology precesses at between 20 and 30 radians.

It is well known that the ability of the gyro to respond to directional forces is proportional to the angular velocity that reaches him, expressed, say, in radians, and think of how sensitive have become his faculties when I tell you that the earth is enabled to hold him in complete thraldom, reaching him, as she does, with only 1/14,000 of a radian.

His embodiment and the devices that are employed to render his articulation completely understandable to all men is the gyro-compass, which is found by mariners to be entirely devoid of all the vagaries that obsess the magnetic

compass and render it unreliable, especially on steel ships. One fundamental difficulty with the magnetic compass is that it feebly points to the constantly moving north magnetic pole, which averages some 1,800 miles down from the true pole that we have to use in all navigation.

The gyro compass is the prime controlling force of its many "repeaters" distributed at all navigational, radio and observation stations on a ship, as well as of the course recorder. It also constitutes the directing force of "Metal Mike," which now automatically steers practically all great ships of the merchant marine, many of them having made the cruise around the world.

So modern science has taught us how we may both lay out and hold our great fleets on the straightest course ever, without the hand of man, and, strange as it may seem, they are actually steered by the steady and unfailing rotation of the earth.

By Elmer A. Sperry, Vice-Chairman, Engineering Foundation.

NINE HUNDRED SLAVES APIECE

Some Contributions of Electric Research to Modern Humanity

E. E. FREE

There is now rising in New York City a vast building which will house the terminus of a pipe line. This pipe will not bring water. Instead there will pour out of it each hour, for the service of the city, the labor of ten million slaves. These slaves will be electric ones; the building is the new

East River Power House of the New York Edison Company, rated at a million horse-power which is more than ten million man-power. The powerful streams of electrons which will pour out over its wires are as truly the slaves of the citizens as were the regiments of Nubian captives who served Pharaoh.

The metaphor of a pipe line is apt, for through great power houses, in each American city flows to its citizens a part of their daily portion of the benefits of science. Too many people think of the results of scientific research as being facts buried in books, unreadable except to experts. These books are only containers. The real results of science are the benefits it gives mankind.

Ninety-six years ago in London a simple, retiring man named Michael Faraday was preaching on Sundays in the chapel of the austere sect to which he belonged and spending the other six days putting together bits of wire and steel and what-not in the basement of the Royal Institution. He discovered a fact called electromagnetic induction, which means that one magnetized bit of iron or one wire carrying an electric current can influence another a short distance away.

These facts were not then known to be of any use. Electricity was expensive and scarce. All the electricity that Faraday or his contemporaries had to work with was made from batteries like those we once used for doorbells or from frictional electric machines producing sparks like the sparks you can draw from the fur of a cat in cold weather.

Working at the same time were Ampere in France, Joseph Henry in America and a host of others. Results of these men's labor pour out now through the pipe lines that begin

at our power houses. Only by virtue of researches on electromagnetism which Faraday and others completed in those long ago days can we now convert the energy of coal into the power of electricity and send out this electricity over wires to light our houses, to run our street cars and to perform each year an increasing percentage of the daily tasks that irk us.

Inside the great dynamos of the new power house in New York, as of all similar power houses in other cities, are a multitude of small coils of wire and of small magnets. Either the coils or the magnets move as the dynamo rotates; sometimes both do. As they pass each other pulses of electric current are set up in the wire. That is exactly what Faraday was working with. He was moving magnets past coils of wire and discovering that electric currents were thus produced. We have only made larger and more efficient machines for doing this, so that we not only have vastly more electricity at our service than any man of Faraday's time could have, but we have it at enormously less cost.

During the past nine decades many scientific men have helped this development. Each has poured his best into the pipe line. Mankind enjoys the result. Scientific research is filling a vast reservoir of needed knowledge. Workers in our universities and industrial laboratories, add what facts they can. Future generations will enjoy the fruits of what we do now as we are enjoying, at the wire-filled mouths of our power houses, the fruits of what Faraday began ninety-six years ago.

The extent to which electricity has remade the world is seldom appreciated. We used last year in the United States more than one hundred billion man-power of electricity.

Man-power is more impressive than horse-power. If we tried to get these same tasks done by actual human labor, as even the greatest kings of Egypt or of Babylon would have had to do, each man, woman and child would have to own, keep and house about nine hundred slaves; slaves to light the lamps, to draw the chariots, to run with messages and to sweep the floors and to carry us up on their backs to the tops of whatever tall buildings we dared to build.

Another feature of the modern power house is almost equally impressive, the perfection of its automatic control. In the new East River Station a glass-protected gallery, high up on one wall of the vast thousand-foot hall that houses the nine turbines and their dynamos, looks down on all the acres of machinery where tiny men here and there are testing or oiling or looking to the bearings or the valves.

Here sit men who hold the nerves of the power house. No mere man starts any dynamo or turns any valve. The electric slaves do that for themselves. Tiny switches and buttons in the control gallery, high up behind its noise-excluding glass, tell the dynamos and turbines and boilers what to do. Tiny lights on a switchboard which fills one whole side of the room in front of the operators announces that whatever was ordered has been done.

What the power houses of a hundred years from now may be like no one would dare to predict. Probably they will be as different from those we have today as Faraday's jars full of chemicals to make a battery were from New York City's newest castle for its millions of electric slaves. But whatever is to come we may be sure that its foundations are now in preparation in our laboratories of scientific research. The

pipe line of science flows forever and its flow seems never tc grow less.

Contributed by E. E. Free, Ph.D., Member, American Institute oi Mining and Metallurgical Engineers.

METALS IN PLANTS

Their Importance to Humans

J. S. McHARGUE

Seeking knowledge about vital processes of nature, researchers began to note a century and a half ago the presence of metals in soils on which vegetation grew. Chemistry and metallurgy were then immature sciences. A number of metals were unknown. Even fifty years ago many were curiosities seen only in jars on laboratory specimen shelves.

Progress in chemistry and physics and improvement in research technic and equipment have in recent years added rapidly to information. Biologist, agronomist and physiologist, also became interested, for minute quantities of metals were found consistently in plant structures and fruits. Why are metals in plants? How do they get there? Can they be regulated for good or ill?

In living structures and in soils from which plants feed metals do not occur in metallic form but as compounds with other chemical elements—oxides, sulphates, phosphates, for example. Only certain soluble compounds can be utilized by plants through their feeding processes, or metabolisms.

Until recent years, it had been taught that only ten chemical elements were necessary for the normal growth of crops:

carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron. Naturally, in the early days of agricultural science, elements occurring in largest quantities received first consideration.

Research has shown that at least eight other elements, although occurring in minute quantities, are important in life processes: manganese, copper, zinc, boron, barium, strontium, iodine, arsenic. They have been found in many kinds of plants. Although essential for life in right forms and quantities, they are poisonous in excess or in other forms.

Three lines of study have been pursued: analysis of soils and plants, carefully controlled growth, and applications for prevention or cure of disease.

Manganese is as widely distributed in nature as is iron, though less abundant, and its compounds were confused with those of iron, until Scheele in 1774 showed that pyrolusite was the oxide of a different metal. Gahn, the metallurgist, soon isolated the new element, manganese, and then Scheele proved it a constituent of rocks and soils, assimilated by plants. In 1840, Liebig taught that plants might absorb from the soil anything soluble but would excrete from their roots anything not essential to growth.

Sachs in 1864 proved that manganese cannot replace iron, but failed to show that it also is necessary. In 1883, Yoshida isolated from the sap of a lac tree a substance having enzymatic (fermentative) properties. In 1894, Bertrand found 2.5 per cent of manganese in the ash of this substance, which he named laccase. He also found laccase in the green leaves of different species of plants and concluded that manganese had important functions theretofore unrecognized because the quantities were so minute.

In 1914, Miss Brenchley stated that she had determined experimentally that one hundred-thousandth part, or less, of manganese sulphate decidedly stimulated the growth of barley seedlings, but larger quantities were toxic. She concluded that manganese might prove essential to plant life. In 1914, the author reported manganese localized in the pericarp (hulls) of several species of seeds and later that the germs contained even more. He has continued experimentation.

The best criterion for demonstrating the necessity of an element for the growth of plants is to show that plants will not grow to maturity in a suitable medium from which the element in question can be shown to be absent during the experiment. Because the significant quantities are so minute, scrupulous care is necessary to assure the absence of the element from the test soil, implements, plant food, and water, for the metals to be tried occur unsuspectedly in many things.

Only the measured doses must enter the experiment. For example, the test soil for some experiments was prepared from a sand found only after diligent search, by screening through a 10-mesh sieve, washing in running water, removing the iron oxide coating of the grains by treatment with acids, washing with clear water, and final rinsing with distilled water, yielding snow-white quartz. Even the pots in which the plants were grown were specially made.

Thus far the author has tested corn, wheat, oats, soy beans, cow peas, garden peas, garden beans, tomatoes, onions, cucumbers, spinach and lettuce. One of the first signs of lack of manganese is the turning yellow of the young leaves and branches (i.e.: they become chlorotic) because

the plants fail to build up the green substance (synthesize chlorophyll).

Manganese is necessary for this synthesis and for carbon assimilation; it cannot be replaced by iron, copper, zinc, boron, or arsenic. It occurs in largest concentrations in the leaves, and in the pericarp and germs of seeds. Arsenic, boron, copper and zinc also caused marked stimulation when not present in excess.

Copper sprays increase the yield of potatoes and favorably influence their composition as well as controlling insects and diseases. Copper is found in many plants. Arsenic stimulates the activities of the ammonifying, nitrifying and nitrogen-fixing bacteria. Certain compounds of zinc stimulate nitrifying organisms and influence the yield of the crop.

A number of researchers are working on this and kindred subjects. Knowledge being gained is of importance not only in agriculture and horticulture for improving quality, increasing yield, producing a food supply which contains the vitamin factors, and lowering cost of vegetables, fruits, grains and forage crops; but possibly also, in engineering and industry, for quickening the growth of timber, increasing supplies of raw materials, producing new sources of fuel (converting sun energy into mechanical power).

Contributed by J. S. McHargue, Ph.D., Agricultural Experiment Station, Lexington, Ky.

"MUCH ADO ABOUT NOTHING"

Usefulness of Vacua

W. R. WHITNEY AND L. A. HAWKINS

Strive as they may, scientists have been unable to attain a vacuum wherein a cubic inch includes fewer molecules than there are people in the world. Even so they have succeeded in removing 99.99,999,999 per cent of the gas. In other words, only one of every 10,000,000,000 molecules remains; yet there are 40,000,000,000 molecules in every cubic inch; the population of the earth is estimated at less than 2,000,000,000.

Across the broad girth of America, from New York to San Francisco, a four days' journey by train, thirty hours by swiftest airplane, imagine a great belt of fine sand a thousand feet, or nearly a fifth of a mile, in width and ten feet deep. Its length, from coast to coast, would be more than 2500 miles. Then imagine it suddenly reduced to a line, so slender as to be almost invisible, just two grains broad and one grain deep.

That is a graphic illustration of how completely a modern Coolidge x-ray tube is exhausted of air by the high efficiency Langmuir condensation pump in the research laboratory of the General Electric Company. The great beach with its millions of millions of grains of sand is symbolic of the cubic inch of air at atmospheric pressure, if each of its molecules were enlarged to the size of a grain of sand one one-hundredth of an inch in diameter, and the line two grains broad and one grain deep represents the almost complete vacuum obtainable with the Langmuir pump. No vacuum known to science is absolutely complete.

The swiftness with which the air is drawn out is equally marvelous. If from a vessel holding a quart there were removed a million molecules a second, it would take 750,000,000 years to remove practically all of its air; but the Langmuir pump accomplishes this in just two seconds.

It can hardly be said of a vacuum, as we know it, that "There's nothing in it." Materially, there are countless thousands of molecules in the highest vacuum attained; there is also endless interest and utility. In fact, the American public is paying more than a million dollars a week for glass-contained vacua.

Ability to create even partial vacua in enclosed spaces has been of great use. It has made possible suction pumps, thermometers, incandescent electric lamps and many improved physical and chemical processes, and has increased the efficiency of steam engines and turbines.

At night we see largely by the aid of vacuum lamps. By means of other vacuum lamps (x-ray tubes) we can also see through opaque bodies. Our transcontinental wired telephony is possible through vacuum tubes, which, in various forms, also permit our radio broadcasting and radio reception from the most remote stations. One of the latest achievements of science, the transmission of photographs by wire or wireless, incorporates still another vacuum tube, the photoelectric cell.

The workman who keeps his drink hot or cold in a thermos bottle is indebted to Sir James Dewar's application of the vacuum, but the scientist is still more indebted to it. Our steam-power plants, including turbines, also owe their success to vacua.

Vacua are of different types. For the steam turbine, a

rough vacuum is sufficient—about an inch of mercury. Incandescent lamps formerly required the best vacua available, but there are now other commercial vacua necessarily quite superior, such as those for x-ray and radio tubes, and for the newly developed cathode ray tube.

So much for vacua within enclosed spaces on our planet. We have reached the point where only one of ten billion molecules remains in as perfect a vacuum as we have attained; but Nature has far outdistanced us. It appears evident, or at least probable, that the condition which humans call vacuum is the natural state throughout the vastness of interstellar space, and some of the stars—millions of miles in diameter and countless millions of miles away from us—are but superheated gases, less dense than the residual gas in the most nearly perfect vacuum tube we know.

Based on information supplied principally by Dr. W. R. Whitney, Director, and L. A. Hawkins, Engineer, Research Laboratory, General Electric Company, Schenectady, New York.

MOLDING RUBBER WITH ELECTRICITY

A New Electrolytic Process

W. C. GEER

Man has long used rubber to keep electricity where it belongs. Recently some research chemists have been showing how to use electricity to put rubber where man would like to have it. Incidently, much power-consuming, cumbersome equipment for forming certain kinds of rubber goods to prepare them for vulcanization appears to be doomed to

scrap-heaps and some disagreeable work places will be transformed.

Patient scientific research, utilizing modern knowledge of the way matter is put together, has again been richly rewarded. As has occurred more than once, independent workers almost simultaneously made practically identical discoveries. Again research is revolutionizing an art; rather, a new art is being built which will in part supplant old methods and in part create new satisfactions for human needs.

Better methods have long been sought for manufacturing rubber goods from the latex, or sap, of rubber trees. Rubber is not soluble in water, but latex and some other forms of pure and compounded rubber can be suspended in water by dispersing them into very minute globules. These "suspensions" or "dispersions" for some purposes resemble a solution, although in other respects quite different. In water dispersions the globules of rubber carry negative charges of electricity; consequently, when a current is passed through them the minute bits of rubber go to the positive pole, or anode. Some searchers for new methods gave attention to this knowledge.

In 1922, S. E. Sheppard and L. W. Eberlin, working in a laboratory of the Eastman Kodak Company, at Rochester, New York, and Paul Klein, A. Szegvari and a large staff in Budapest, Hungary, found independently that pure and compounded rubber could be electrolytically deposited from water dispersions on to metal or ceramic molds, in a way somewhat like electro-plating with metals. The former group was trying to cover metals with adhering coats of

rubber deposited from water dispersions, and the latter to make rubber goods directly from latex.

Each investigator was practically interested in improvement of the quality of rubber goods. They knew that when the solid dried crude rubber is worked upon a mixing mill in the rubber factory, the rubber substance was altered, depolymerized, as the chemist says, and thereby became softer and weaker. They knew that the less rubber was heated or worked, the better was its quality.

They also knew that research of chemists in recent years had shown how vulcanization may be carried on at lower temperatures than formerly and the necessary sulphur combined with rubber with minimum of loss of quality. Certain substances known as accelerators possess the property of permitting vulcanization to be accomplished at relatively low temperatures. However, if these accelerators were incorporated on the usual mixing mill, the temperatures would be sufficiently high to cause vulcanization during mixing and spoil the goods.

These men conceived the plan of so depositing rubber on forms, from latex, that the rubber particle itself was not altered and made the astonishing discovery that electro deposited rubber had the highest quality ever observed. Many were the problems to be solved before this was made practical. It was necessary to incorporate other substances to be deposited simultaneously on the anode, such as sulphur, zinc oxide and carbon black. These latter two substances are necessary in rubber goods to give toughness. A long investigation was carried out to find means to disperse them in water, mixed with the latex particles, without coagulating the latex.

A noteworthy achievement, which has made the Anode process possible, has been the means by which these rubber layers may be free from bubbles, for when an electric current is passed through a solution, bubbles of gas are formed on anode and cathode. So they hit upon the scheme of surrounding the anode with a porus clay diaphragm. The anode is therefore immersed in electrolyte inside a porus clay cell or dish and the rubber particles together with those of zinc oxide, sulphur, etc. are deposited upon this porus so-called Anode diaphragm. Thus the rubber as it collects forms a continuous, homogeneous, tough covering of uniform thickness.

Any thickness up to an inch or more is practicable. Rubber thus formed is stronger than rubber prepared by the old methods, and is free from gas or air holes. Therefore it is permissible to use less thickness for some purposes.

Industrial development is already well advanced. Continuous, automatic production of certain kinds of articles is feasible. Manufacture of inner tubes for automobile tires is the most important application, if quantity be the criterion. Bathing caps, stationer's elastic bands, tobacco pouches and hot-water bottles are other examples. Insulation for wires and other things electrical in another application.

After being formed of desired thickness, articles have to be dried, cured and removed from the molds. The process may be operated as a continuous cycle. Drying and curing steps also differ advantageously from the old methods. No high temperatures are used. For impregnating textiles the rubber can be more intimately applied to the fibres.

To commercialize the benefits of these researches a company has been incorporated with the name American Anode,

Inc., based on the interests of the Eastman Kodak Company, The B. F. Goodrich Company and the British Anode Company, Inc. European and American leaders in this new field are coöperating in its development.

Contributed by W. C. Geer, formerly Vice-President in Charge of Research and Development, The B. F. Goodrich Company, Akron, Ohio.

CHEMISTRY IN THE DESERT

Research and Human Engineering Win

JOHN E. TEEPLE

This is a tale of how a sickly "war baby" became a lusty chemical industry. It took much scientific nursing and plenty of rich milk. Fundamental research, skillful engineering, sound business economics and loyal coöperation of chemists, engineers and business men would have won anywhere.

The moral would have been the same if the substances under study had been metals or oils, instead of salts. Wartime necessity and situation in the Mohave Desert, not many miles from Death Valley, in the southern part of California, add romantic interest.

Potash is essential to agriculture and is useful in many other ways. Continental U. S. A. consumes each year about 250,000 tons of K_2O, as the chemist labels it with his symbols, of which over 90 per cent goes on to the land. Before the World War, this country produced only an infinitesimal quantity. War cut off our supply from Germany.

There are a number of sources from which potash can be gotten in these United States if cost is not a consideration.*

* See Research Narrative 92.

War exigency multiplied the price. More than 120 plants were created to produce potash in various ways in several parts of the country. Two of them were at Searles Lake, in the Mohave Desert. In 1918, production from 123 plants attained the maximum of 54,000 tons K_2O.

In July, 1922, potash was on the "free" list of the tariff and only one plant was in commercial operation, one of those at Searles Lake, and it had produced only 3000 tons during the last year. Here the adventurers had invested up to 1919 more than $6,000,000 and the source of raw materials appeared to have possibilities. At any rate, one stubborn chemist got a vision of an American plant producing potash and other chemicals, at a profit, in competition with the world, and "thereby hangs our tale."

Searles "Lake" is a bed of crystallized salts about 12 square miles in area, 60 to 70 feet deep, permeated with brine, and fed by underground streams. Summer evaporation keeps the brine an inch or so below the surface of the salt. In winter, brine stands an inch or more deep on top. In this "lake" are eight salts of sodium, potassium and boron, including some 36,000,000 tons of potassium chloride. The composition of the brine is uniform and its temperature throughout the year, 23 degrees Centigrade (73 Fahrenheit).

The stubborn chemist first got assurance that enough patient money would be forthcoming to carry through the researches and reorganization. Then he picked a few young men who liked work and responsibility and had the hardihood to work and live in the desert. He showed them his vision. With the bait of a big pioneer venture, this nucleus drew other ambitious souls.

He assured them the project would be completed, that each

would have all the work and responsibility he was capable of taking, and that there would be freedom from bossing and interference. The group became an organism, a living, growing, coöperating entity, made up of self-reliant, unafraid, resourceful individuals, disregarding personal comfort 115 degrees in the shade, or 24 hours a day.

The stubborn chemist certifies to his readers that there are plenty of men who will work their heads off intelligently and accomplish marvels, if management will realize, and make them realize, the dignity and importance of their work, give them authority along with responsibility, free them from nagging, from gloom spreaders, from constant dictation, and ask only for final results in scientific achievements coupled with economic success. And pay checks must maintain an encouraging relation to work done. From an establishment so managed the weak, the petty and the deadwood will disappear. Any man who is not contributing his best feels lost and fades away.

Trona, for so the place was called after one of the salts in Searles Lake, was, in 1919, just a desert mining camp. The labor turnover was 500 per cent per year, an entire new force on the average every ten weeks. In 1926, turnover was normal. Trona is now a beautiful town of a thousand inhabitants, with tennis courts, golf links, swimming pool, steam heat, running water, electric lights, and the other comforts of American civilization, including afternoon tea and "bridge."

Chemical and engineering problems were mastered without stint. Here's a sample. Foaming in the evaporation process in the plant made much trouble and expense. Why? Research finally proved that some organic substance in the

brine must be the cause. What? The desert tributary to the lake had but few fauna and flora. Nevertheless, Larrea mexicana, the creosote bush, which with cactus and sage constitute most of the vegetation, was found to be the culprit. Research also provided a simple remedy, and foaming ceased.

Now the American Potash and Chemical Corporation can produce in the 1919 buildings, nearly 400 tons daily of potassium chloride, borax and boric acid of very high grade, at prices below pre-war, with a profit. Instead of tradition, a loud voice and a strong arm, the plant is run on meters, thermometers, charts and accurate knowledge.

Every minute a ton of salt must be washed free of liquor and discharged from the plant. Every minute 200,000 gallons of liquid pass through pumps, apparatus and miles of pipes. The annual freight bill is $2,500,000. Research goes on, seeking other profitable products from the raw materials and greater economy in all operations, from getting the brine into the plant to marketing and purchasing. Research, intelligently managed, pays.

Extracted from articles contributed by John E. Teeple, Ph.D., Member, American Chemical Society, New York.

INSECT CARRIERS OF PLANT DISEASES

Defensive Researches

L. O. KUNKEL

Insects spread the germs of plant diseases just as they do those causing human and animal diseases. Because plants are unable to move about as animals do most of them have no effective means of defending themselves against the swarms of insects that feed upon them or suck the juices from their tissues.

Everyone who grows plants knows of the injury done by the feeding of insect pests. But not everyone knows that the injury thus caused is sometimes far less important than the damage that results from insect transmission of plant diseases.

A considerable number of infectious plant diseases caused by protozoa, bacteria and fungi are spread by insects. But it is in the virus-disease group of plant maladies that the spread of disease by insects is most serious. So far as known all of these diseases depend on insects for transmission to healthy plants. In some instances such transmission is doubtless nothing more than a simple mechanical transfer of infected juice to feeding wounds made in healthy plants. In other cases, however, there is evidence that a specific relationship exists between these diseases and their insect carriers.

Aster yellows, a disease which attacks the China aster and many other cultivated plants, furnishes an excellent illustration of the intimate relations that exist between certain virus diseases and their insect vectors. Aster yellows is not spread by seeds from diseased aster plants or by the soil in

which diseased aster plants have been grown. Neither is it transmitted by contact between diseased and healthy plants. It has not been transmitted mechanically by man except by grafting. Several sucking insects that feed on the aster are unable to spread the disease, but the gray aster leafhopper *Cicadula sexnotata* Fall, readily transmits it to healthy plants.

Before the aster leafhopper can spread yellows it must first feed on a yellowed plant, but it is unable to transmit the disease immediately after feeding on a sick plant. At least ten days must elapse between its first feeding on a sick plant and the time when it is first capable of transmitting yellows.

This ten-day incubation period of the virus of aster yellows in the leafhopper suggests that the agent causing yellows undergoes development in the body of the insect and indicates that a very specific relationship exists between the disease and its carrier. After the incubation period, virus-carrying leafhoppers spread yellows to all susceptible plants on which they feed. Some individuals lose the virus after one or two weeks, but others carry it as long as they live.

The same leafhopper that transmits yellows to the China aster also carries it to more than fifty other species of wild and cultivated plants. Lettuce is one of the most important hosts of aster yellows. On this plant it has long been known in the Southwest as the Rio Grande disease and in New York and other eastern states as the white heart disease. In the winter, yellows lives on perennial weed hosts. During the summer, when the carrier-leafhopper is very active, it spreads rapidly to susceptible annual plants such as the China aster and lettuce.

Spread of aster yellows and its host range depend largely on the likes and dislikes of the aster leafhopper. The African marigold is quite susceptible but seldom takes the

disease even when grown adjacent to yellowed aster plants. The leafhopper does not like the marigold and seldom feeds upon it when other plants are available. If confined in a cage containing only marigold plants, hunger drives the leafhopper to feed upon them and they readily take the disease. It is fortunate that although wheat and other cereal crops are favorite hosts of this leafhopper, they are immune to the yellows.

The aster leafhopper is thought to have been accidentally introduced into the United States from Europe fifty or more years ago. Although it is prevalent in Europe and the Orient, where the China aster is extensively grown, the aster yellows disease is known only in America. Thus, a disease which is apparently endemic in America has been rendered much more serious through the importation of a European leafhopper, *Cicadula sexnotata,* and of an Oriental plant, the China aster.

No satisfactory means is known of controlling the aster leafhopper, but the yellows which it spreads can be held in check by digging out all infected perennial weed hosts in the vicinity of the field to be protected and by destroying all diseased annuals as soon as observed. A yellowed plant is a menace to nearby healthy plants just as a malaria patient is a menace to a healthy community in a region infested with the mosquito, Anopheles.

Man's most dangerous and destructive enemies are the little fellows—germs, insects, rodents. They attack both his person and his supplies. This Narrative tells of one of the hundreds of researches which have been made and must be made in defence.

Contributed by L. O. Kunkel, Ph.D., plant pathologist at Boyce Thompson Institute for Plant Research, Inc., Yonkers, New York.

HARDENED COPPER

A Recovered Art

WILLIAM G. SCHNEIDER

There exists, on the part of those not intimately connected with the working of copper, a belief that the ancients had a method of hardening that metal, with which art we today are not familiar. The fact of the matter is that our present-day metallurgists not only understand how the ancients hardened their copper and bronze, but also know how to produce copper and bronze products that are even harder than those left to us and which represent the evidence of the so-called lost art of hardening copper.

Cutting edges developed on swords, daggers, knives and other implements by the ancients were obtained by hammering the metal, or, in other words, cold-working. Those old metal-workers not only hand hammered their copper implements but also used the same means to harden other bronze articles.

The heating of many of these products in open fires resulted in the formation of considerable copper oxide, which alloyed with the copper and hardened it. One of the most common mistakes of persons claiming to have rediscovered "the lost art of hardening copper" is to heat it in a forge and in this way saturate it with copper oxide, which combines with the copper to form a much harder and much more brittle product.

There are really two methods of hardening copper that are regularly practised nowadays, just as centuries ago. One consists in alloying the copper with some other metal or

several other metals such as zinc, tin, nickel, cadmium, chromium, cobalt, silicon, aluminum, iron, beryllium and arsenic.

The second method consists in cold-working the metal or copper alloy. In fact, it is possible to work the metal to such a stage of hardness that a slight amount of additional work will cause it to break. The explanation of all copper hardening may be attributed to one of these methods or a combination of them.

Microphotographs of an ancient copper spearhead indicated that it was extremely hard and that apparently this hardness had been obtained by cold working.

Copper scissors, knives and other cutting tools may be obtained. Unless, however, a special reason exists for their use, they offer no advantages over tools made from steel. Occasionally, however, it becomes necessary to use copper or bronze tools, such as knives. Around a powder plant, for instance, where all sparks must be avoided, bronze knives are almost essential.

The actual hardness of annealed commercial copper as determined by the Brinell machine (an instrument for measuring the hardness of substances) is from 40 to 50. The hardness of cold-worked pure copper probably does not ever exceed 120 Brinnell. The hardness of copper that has been alloyed with some other metal or a number of metals but rarely exceeds 250 Brinell, although a hardness just over 300 has been attained as an upper limit.

As a basis of comparison for readers unfamiliar with measurements of the hardness of metals, it may be stated that the Brinell hardness of very "soft" iron is around 80

and of steel used in common cutlery, such as in a finished pocket knife, about 420 Brinell.

Not only do many persons spend a short while endeavoring to rediscover an art that never was lost, but some of them devote a whole lifetime to this effort. The tragedy, or rather, the denouement, occurs when they have evolved a hard copper. They next endeavor to find some use for it and then learn that, unless it has some special properties, no market exists.

Copper wire, hard drawn, has a tensile strength of about 65,000 pounds per square inch and an elongation in 10 inches of about one per cent, with a conductivity of about 97 per cent. This affords some basis on which to work when endeavoring to develop the hardening of copper. If, for example, it were possible to harden copper so that the tensile strength were materially increased above that just stated, without reducing the conductivity, a worthwhile discovery would have been made.

Some recent methods of hardening copper by alloying have, to a certain extent, come about as near to actually "tempering" copper as would seem possible. In these methods the metal, silicon, plays a most important part because it forms silicides with other metals which in turn form eutectics with the copper.

The deoxidizing effect that silicon by itself exerts plays no unimportant part in finally allowing the metal to be worked and by heat treatment to develop a high strength, with a relatively high conductivity. This latter, however, is considerably below that of pure copper and second only, speaking of alloys from the standpoint of both strength and conduc-

tivity, to those of copper and cadmium. Alloys of copper with cadmium give, for a stated conductivity, higher strengths than those with silicon.

Contributed by William G. Schneider, Copper and Brass Research Association, New York; Member, American Institute of Mining and Metallurgical Engineers, Mining and Metallurgical Society of America, American Electrochemical Society.

CARBON FIXATION BY PLANTS

Nature's Most Fundamental and Inefficient Process

JOHN M. ARTHUR

Approximately 1,750,000,000 human beings are eating 2,000 kilogram calories of food per day. In a year this energy amounts to about 12 x 10^{14} kilogram calories, (12 with 14 ciphers, a number too large to call by name). We might guess that all other vertebrates, the invertebrates, and the soil micro-organisms are consuming about 6 times this amount. Total yearly consumption would then be 84 x 10^{14} kilogram calories. All of this energy was fixed from sunlight by green plants, by one of nature's most inefficient processes, photosynthesis, (combining substances by means of light).

Since only about one per cent of all solar energy falling on green plants is utilized, we might think that we have parcelled out energy too liberally; a few calculations on the income side are of interest. The earth has a land area of 55 million square miles, of which probably half has a crop of plants growing upon it 6 months each year. Assuming that 500 gram calories of solar energy per square centimeter are received on the land area each day during 6 months and that

one per cent is fixed, we calculate that 64×10^{16} kilogram calories are fixed in a growing season.

This is about 76 times 84×10^{14}, the energy value arrived at from the estimated total consumed, and indicates that our first guess was extremely conservative. The quantity 64×10^{16} kilogram calories is equivalent to the energy in about 89×10^{11} tons of anthracite, or about 8,900 times the annual world production of coal. The human race consumes annually less than two-tenths of one per cent of this value.

One of nature's most fundamental processes is only one per cent efficient. An unusual opportunity for an efficiency expert! If only a few tenths of one per cent could be added to the efficiency of photosynthesis, an enormous increase would be available in total energy fixed when applied to nature's vast quantity production.

Over one hundred years ago, de Saussure showed that green plants not only use the small amount of carbon dioxide normally in air but can use more when available. These facts indicate a means of increasing the efficiency, yet no application was made until the recent world war. Then, under pressure of food shortage in Germany, processes were perfected by Riedel and others for scrubbing gases from combustion of coal, coke and charcoal to produce carbon dioxide. The gas was piped into greenhouses among growing plants. With high temperature and high light intensity a concentration of less than half of one per cent of carbon dioxide will about double the dry weight of plant tissue produced.

About fifty years ago, Siemens found that in winter when light intensity is low, addition of light from an arc lamp gives a noticeable increase in the growth of many plants. Photo-

synthesis increases with temperature and with carbon dioxide supply within limits. It also increases with light intensity and day length up to a certain maximum.

If a plant is given all the light energy it can use for fixing carbon and all the carbon dioxide it can fix, along with a favorably high temperature, what rate of photosynthesis can be maintained? Can we produce wheat, lettuce or tomatoes in a week or a month under these ideal conditions?

Equipment has been collected at the Boyce Thompson Institute for Plant Research, Inc. for answering some of these questions. Several kinds of plants have been grown both with artificial light entirely and with different combinations of daylight supplemented at night with artificial light. Some plants received continuous 24-hour illumination of high intensity, coupled with a high temperature and an increased concentration of carbon dioxide.

Many plants could be grown from seed to maturity in a remarkably short time. Spring wheat was grown from seed to head in the brief time of 35 days; it needs no rest and will maintain photosynthesis at a high rate, 24 hours per day, during its life.

The tomato under similar conditions will die out completely in about 2 weeks. It is not able to maintain photosynthesis near its maximum rate. Twelve hours of daylight with 6 hours of artificial light, making an 18-hour day, is all the tomato can withstand.

Lettuce will produce a large head in about 3 weeks on an 18-hour day. After this it will send up a seed stalk. If kept on 12 hours or less, it does not produce a seed stalk. Red clover plants thrive on a 24-hour day; a crop was grown from seed to flower in 38 days.

1500 kilowatt hours of electrical energy were used each day during the growth period of these plants, not with the hope that some practical application might be found in growing plants commercially, but for the purpose of learning the effects of environmental factors on photosynthesis. From researches like these may come in time new means for producing some foods and fuels and other supplies for human needs. Economic achievement, however, yet appears remote except in small scale operations.

Contributed by Doctor John M. Arthur, Boyce Thompson Institute for Plant Research, Inc., Yonkers, New York.

ANOTHER EVOLUTION

Electric Welding and Flame Cutting Revolutionizing the Building of Machines

R. H. ROGERS

Anecdotes without number might be written of the heartbreaks, delays and losses attributed to castings. Nevertheless, for many purposes castings still have advantages all their own. Some of their limitations are, however, especially objectionable in large machines which have to be individually designed.

More than one story might be written somewhat like the following, as most persons who have used castings of iron or other metals extensively can bear witness. Of course such experiences are not often recorded in print.

The company secured the contract for the electrical equipment for a large water-power development. Nature makes

no two waterfalls alike in height, in quantity of water, in distance from places of use of the power. Hence the electrical generators for their plant could not be just like any made before; some parts had to be much larger. For the base, the stator frame and other parts, huge castings were required.

As the designer bent over his table the parts took shape in his trained imagination and were delineated upon the drawing paper. Constantly questions ran through his mind: Can the pattern-maker build this? How must he divide it so that the pattern can be gotten out of the sand mold? Will the molten metal flow into this part readily? Will the flowing metal "cut" or "wash" the mold here, injuring the casting in more ways than one? Can that pocket be vented of the gases liberated from the molten metal? Will this part crack away as the metal cools and shrinks? Will that very thick part be spongy? And so on.

Under the guidance of experienced engineers and metallurgists, the designers, pattern-makers and foundrymen provided for one difficulty after another. Finally, after months of preparation, the hour for the great adventure arrived and the metal was poured. More days went by as the casting was slowly cooled, stripped and cleaned. Tons of "gates" and "risers" were cut away. A rigid inspection was made, possibly with the aid of X-rays in search of hidden flaws. Then the casting was shipped to the machine-shop.

One after another certain parts of the casting were machined on boring mills, planers or other large machine tools. Some spots were hard to cut because sand or scale got into the molten metal while the casting was being poured. The last face was being machined; the tool gradually un-

covered a narrow crevice. Probing revealed a thin cavity extending into the casting at a place where soundness and strength should be unquestionable. The casting must be rejected!

Months of time were irrecoverably lost, together with great expense incurred in foundry and machine-shop and for transportation. And the same risk must be taken again. Loss of interest and income also must be borne. Is there any escape? At last Science and Engineering are beginning to say, Yes! How?

Modern markets offer a great variety of slabs, plates, bars and structural "shapes," produce of steel mills by processes which assure metal of high dependability and uniformity of mechanical and electrical qualities, easily machined or welded or cut by flame torches, stronger and tougher than castings of iron. Their surfaces are good enough for many purposes. Dimensions are very close to standards. Wastage of metal is much reduced together with the net weights. Uncertainties are almost eliminated. By their use in construction of machines a large burden of anxiety is taken off the nerves of the manager.

The designer enters a new field of wider freedom wherein materials and technique more closely satisfy the principles underlying his work. He no longer has to use metal an inch thick and liable to breakage where a tough $\frac{1}{8}$-inch plate is much better. Construction may begin as soon as designs are developed. No waiting for castings! Economy, adaptability and other advantages in many features are realized. Storage for patterns and their loss by fire disappear.

Designers no longer are hampered by economic necessity to re-utilize old patterns. Time is saved; costs reduced.

Some machines can be completely fabricated in less time than formerly was consumed in making patterns. Predictions of cost and delivery can be made with less uncertainty.

In the new technique, steel up to 8 inches thick is flame cut within $\frac{1}{32}$-inch of desired dimensions, with surfaces smooth enough to be painted or requiring but light cuts if they are to be machined. Flame-cut parts match satisfactorily for welding. Half-inch plates are cut at a rate of 15 inches a minute, and 2-inch plates at $7\frac{1}{2}$ inches. Welding is done by electric arcs on machines which make most of the operations automatic and more rapid than handwork.

Again Science and Engineering are leading Industry into new paths and bringing benefits to the people.

Based on information supplied by R. H. Rogers, Industrial Engineering Department, General Electric Company, Schenectady, New York.

AN EXPENSIVE INCONSISTENCY

An Electric Cable Problem Solved by Research

WILLIAM A. DELMAR

With multiplication of the uses of electricity in factories, offices and homes and the growth in size of cities and towns, the quantity of current demanded increased greatly. For the most part, the electric energy is generated in central power stations. These stations are either hydroelectric, situated where water power is available, or steam, situated where fuel and the water required for condensing the spent steam can be most cheaply provided. Whatever the

primary source of energy, the electric current is sent over wires to the places of use.

In supplying water to communities, if the quantity is to be increased, more or larger pipes must be used or the pressure that forces the water along must be raised. Likewise, in transmitting electricity there must be more or bigger wires or greater pressure. In dealing with electricity, a new term, voltage, was introduced, corresponding to pressure in pipes carrying fluids.

For crossing the open spaces of rural districts, electrical engineers found it most economical to increase the voltage to high figures; but high-voltage electricity is to be treated with respect and so the wires were strung on high poles or towers to be out of the reach of persons who might otherwise come in contact with them. This required much space because also the three wires commonly used had to be kept some distance apart.

Within cities and towns wires on poles or towers carrying high-voltage current are dangerous, inconvenient and unsightly—in short, impracticable. Cables were the alternative, but cables have to be made up of insulation in addition to the wires carrying the current.

The best insulation available when need for electric power cables made itself known would not hold very high voltage. Consequently, endeavors of researchers, engineers and inventors were directed toward the devising of cables which would carry high voltages efficiently and safely.

A few years ago, electric cables for circuit voltages of 33,000 and more became a commercial necessity. Several manufacturers furnished large quantities of such cables to the leading electric light companies, after conducting exhaustive

tests to satisfy themselves respecting the quality of their products. These cables stood test voltages of several times the operating voltage, were successfully subjected to hot and cold life tests at their operating, or even higher, voltages, and in every way the stage seemed set for an immense expansion in high voltage underground transmission.

To the dismay of both the operating companies and the manufacturers, trouble began almost immediately and most of these cables had to be reduced in voltage or scrapped. Cable which was taken out for examination stood every test that could be devised to prove its quality. Some of it was reinstalled, but soon failed in service.

The situation could be summed up briefly in this way: Cable which appeared to be perfect when tested in reel lengths was worthless when tested or operated in feeder lengths,—the lengths needed to feed the current from the central station to the places of distribution or use.

The manufacturers at first could conceive of no explanation except that voltage surges were occurring in the feeders, which did not occur in the reel lengths. To test this theory the operating companies carried out extensive tests, which showed that voltage surges are not serious on underground high voltage lines. At the same time the manufacturers tested their cables with short applications of very high voltages and found them amply able to stand the surges which actually occurred.

An impasse seemed to have been reached, due to the inconsistency of behavior of long and short pieces of cable. Laboratory research co-ordinated with field observation came to the rescue and solved the problem.

It was found that the static pressure within a cable varied

with temperature and other conditions and that whereas in a reel length equalization of pressure was fairly rapid, so that the insulation would always be at approximately atmospheric pressure under test conditions, due to the ends being open, a cable in operation could vary in internal pressure from less than a half atmosphere (partial vacuum) to over one and a half, due to the section ends being hermetically sealed at the splices.

It is well known that ionization of gases (an electrical change accompanied with greater chemical activity) occurs at much lower voltage or more violently at the same voltage in semi-vacua, so that destructive discharges could occur in a long feeder at voltages which would not affect a reel length in any way. This was found to be what was occurring in long feeders.

The cure for the trouble was obviously the use of devices for introducing and maintaining suitable internal pressure in the installed cables. This has been successfully accomplished by various means, such as pressure chambers in or attached to splices, bellows reservoirs connected to splices, and oil stand-pipes.

All high tension cable systems are now being equipped with such devices, and systems are in successful use on a large scale, not only at 33,000 volts, but at 40,000, 45,000, 66,000, 75,000 and for the last few months, 132,000 volts.

Contributed by William A. Del Mar, Fellow, American Institute of Electrical Engineers, Chief Engineer, Habirshaw Cable & Wire Corporation, Yonkers, New York.

ARCH DAMS

A Unique Research in Civil Engineering

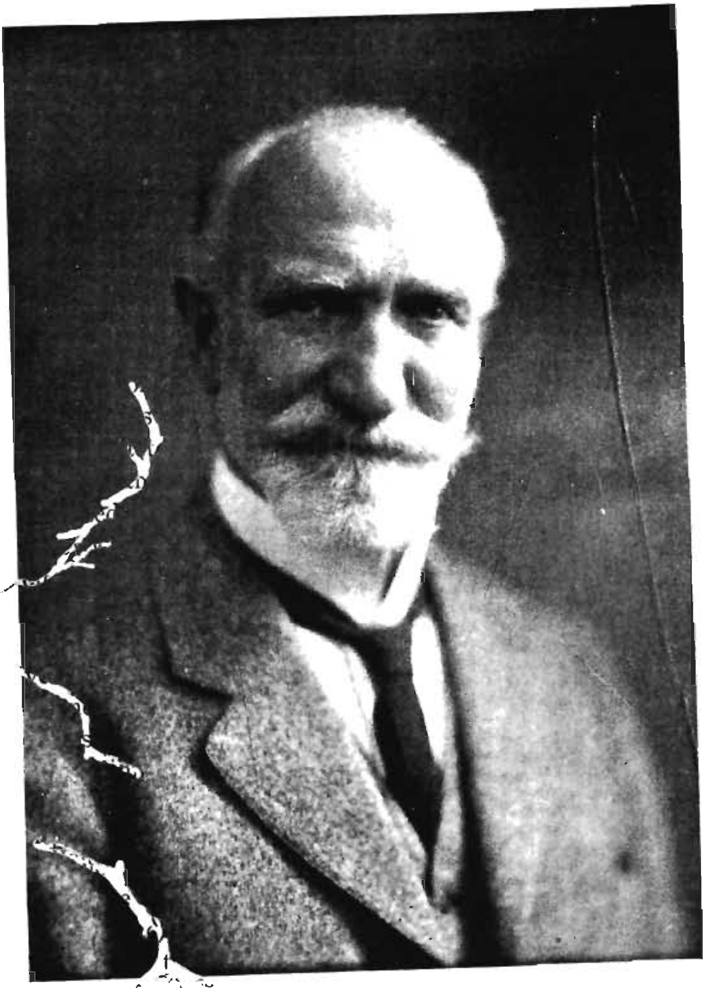
CHARLES D. MARX

Water serves humanity in many ways, yet few persons know how engineers control it. Rain falls and snow melts irregularly; there are floods and droughts. In many places water must be stored, or its level raised, or its course changed, for development of hydro-electric power, for water supply of communities, for irrigation, for flood control, for navigation in rivers and canals.

Dams are means to these ends. Some dams are walls of concrete or other masonry, of a variety of shapes. As engineers have been emboldened by experience, dams have been built higher. Many now exceed 200 feet and a height of even 700 feet has been considered. Because stored water becomes vitally necessary to those dependent upon it and because the breaking of a dam would in many places destroy life and property, dams must be unquestionably safe. Yet they may not be too costly.

A few centuries ago an engineer conceived that curving a dam upstream would make it stronger. A curved dam would in some situations act as an arch stood on its edge; hence engineers took advantage of the arch strength as revealed in bridges and buildings. A single curved wall will act as an arch only in a narrow canyon, or gorge, with steep rock sides. Also engineers used for dams across wider valleys series of arches, between buttresses.

Arch dams developed on assumption and theory. With safety in mind many curved dams were made so thick they



PROFESSOR CHARLES D. MARX

could have but little arch action. About thirty-five years ago, an engineer built a dam in Bear Valley, near Redlands, California, so thin that conservative dam builders gasped. It still stands. Other thin arch dams were built in several countries. None built by an engineer has failed.

There was divergence of engineering opinion. Experimental knowledge was much desired, but obstacles were forbidding. In 1922, Engineering Foundation undertook an investigation. A committee of engineers was organized. Observations on existing dams were undertaken, but this method was difficult and slow. Available instruments were not satisfactory. Consideration was given to models and to methods and instruments. A meeting of the committee was enthused by a proposal from a large power company to build an experimental dam fifty to a hundred feet high, and the offer of a substantial contribution.

Financing and planning went along together. Power companies, industries, bankers, governmental bureaus, universities, American and foreign engineers joined Engineering Foundation in carrying on the investigation. Better instruments became available, some being devised especially by sub-committees and collaborators.

For this full-size experiment favorable conditions existed not likely to be duplicated in many years. In the Sierras, 60 miles east of Fresno, California, Stevenson Creek tumbles down the mountain through a granite gorge into the canyon of San Joaquin River. On this creek was an ideal spot. It was near a tunnel through the mountain conveying a great volume of water to a power plant.

A small pipe, controlled by valves, led from the tunnel to the creek, above the dam site, so that the reservoir could be

filled as desired, like a tank in a laboratory. The reservoir was so small that the quantity of water needed was unimportant. Even if the dam should break while the reservoir was full, no damage would result. The power company was constructing extensive works in the region. Hence a works railroad, a highway, electric light and power, equipment, supplies, and skilled men were at hand.

When the excavation in the rock was almost ready for the dam, an untimely flood washed rocks and sand into the trench, causing delay and expense. June 4, 1926, the dam was completed to a height of 60 feet. It was shaped like a symmetrical, triangular piece of the side of a round can, stood on its point, curved upstream.

The dam was built of portland cement concrete without steel reinforcement. Thousands of parts of instruments were embedded for making tests. Its thickness was reduced gradually from $7\frac{1}{2}$ feet at the bottom to only 2 feet 30 feet above and is 2 feet for the upper 30 feet. It is 140 feet long on top.

Thousands of measurements of strain, deflection and temperature were made with the water at various depths up to 60 feet, and with no water in the reservoir, according to a program, from June to October. To have practically no change of temperature and moisture during a test, measurements were made at night.

Late in November a flood overtopped the dam at least three feet, destroying the observation platforms and many instrument connections and partially filling the reservoir with sand and rock. This prevented cold weather tests planned for January. There was another flood in February. The dam still stands.

A celluloid model one-fortieth the dimensions of Stevenson Creek dam was tested with mercury instead of water. The results agreed remarkably. Models of larger sizes, of mortar and other substances, are being planned of dams of the same shape as the Stevenson Creek dam and several other shapes. Stevenson Creek dam should be built higher and tested until it breaks. Useful information has been gotten and is being made into a book.

Contributed by Professor Charles D. Marx, Past-President, American Society of Civil Engineers, Chairman, Committee on Arch Dam Investigation, Standard University, California.

TALKING TO EUROPE

A Commercial Service Proved Dependable

RALPH BOWN

January 7, 1927, radio telephone service was begun between New York and London. Within the succeeding few months it was extended to all United States and Cuba and to all Great Britain. Narrative 85, July, 1924, told of steps leading to eastward transoceanic telephony by a new system, as an experimental preliminary to operation both ways.

Bell Telephone Engineers set up transmitting equipment at Rocky Point, Long Island, so as to use antennae owned by the Radio Corporation of America. Initial receiving tests were made at three temporary stations on the Atlantic seaboard. The British Post Office constructed receiving stations and equipped for telephony the giant telegraph transmitting station at Rugby. By trials lasting three years

the most suitable radio wave bands were selected. Means for generating, sending, controlling and receiving selected types of electrical energy were developed.

Early in the tests these facts were established: Strength of signal changes radically with time of day, being stronger at night. Amount of radio noise present is usually less in the morning and increases towards evening and well into the night. It is not absolute strength of signal which is controlling, but the extent to which it dominates the noise. The amount of noise in summer is usually very much greater than in winter.

Favorable relation of message sound to annoying sounds (signal-to-noise ratio) could be greatly improved by use of directive antennae which receive efficiently only from the direction of the transmitting station, and, therefore, reduce the effect of noise coming from other directions. So-called "wave antennae" proved to be best.

Results were gratifying since they showed that transmission could be improved just as much as if the transmitting station power had been multiplied one hundred times. For the receiving end the amplifying and detecting apparatus contained electrical band filters which also aided incoming static.

Tests proved that placing the receiving station in a northerly latitude, effected an improvement equivalent to multiplying the power of the English transmitting station fifty times. The final receiving station was built at Houlton, Maine.

The British Post Office, since all Great Britain is north of Maine, decided to build a temporary receiving station near Wroughton, England, leaving a more northern location

for later experiments. To gain advantages soon made evident by tests, the British Post Office constructed a new station at Cupar, near Dundee, Scotland. The transmitting and receiving stations were tied to the terminals in New York and London by suitable wire circuits.

Extensive negotiations were carried through in Europe and America to obtain a suitable "path in the ether" which would be kept free from interference by radio telegraph transmission.

Special apparatus had to be introduced to meet conditions different from those in all-wire telephony over land. To save ether channel space, east-bound and west-bound radio channels are on the same frequencies. Thus the selectivity of the receiving sets does not prevent crossfire from the local transmitter into the local receiving circuit; if no special arrangements were provided the system would "sing."

To overcome this trouble an arrangement of sensitive switching devices was developed whereby voice currents automatically connect the terminal circuit for transmitting or receiving as the flow of conversation demands.

When no one is speaking the transmitting voice paths are blocked at both New York and London but the receiving paths are open. When, for instance, an American speaks his voice currents actuate the device to block off his receiving path and to open his transmitting path so that his voice goes out. Since the other end is in receiving condition, the voice currents travel through to the listener's ear.

When the American speaker has finished, his apparatus is automatically restored to receiving condition and the British speaker is, by similar functioning of the apparatus in London, able to speak. Interlocking arrangements permit the voice

of only one speaker to go through the entire system at one moment; the two speakers are prevented from talking simultaneously without either one hearing the other.

Since it is necessary to deliver signals of the maximum possible amplitude in order to maintain a favorable signal-to-noise ratio, it is essential that the transmitters be kept loaded to full output even though the voice currents vary widely due to differences in voices and in attenuation of connected wire circuits. This is done by a control operator as in broadcasting stations.

The current passes out of the realm of the control operator towards the wire system of the country on an ordinary two-wire trunk which goes to an operating position in the long distance office.

At each end are two telephone operators. One makes contact with the telephone network to make ready connections for attachment to the transatlantic link. The other directs her attention to the transatlantic link and to dealings with her correspondent at the other end, passing call information, making final connections, pulling down connections when subscribers have finished. From the subscribers' standpoint a call is made in the same way as any other long distance call.

And so America now says "Hello" and England responds. But back of this achieved operating service are years of research, survey, invention and engineering of high order. This way lies modern progress.

Contributed by Ralph Bown, Ph.D., American Telephone and Telegraph Company, New York.

NEW LIGHT FROM THE NEBULAE ON THE NATURE OF MATTER

GEORGE ELLERY HALE

August 29, 1864, Sir William Huggins first undertook the analysis of the light of a nebula. Five years earlier Kirchhoff and Bunsen, through study of the sun, had established the powerful method of spectrum analysis, which tells as quickly and surely the chemical composition of a celestial object as the chemist could if he were able to test its substance in his laboratory. More surely, indeed, as the observation of Huggins and its recent interpretation by Bowen will show.

Let us read the classic record of Huggins in his own words: "I looked into the spectroscope. No spectrum such as I expected! A single bright line only! At first I suspected some displacement of the prism, and that I was looking at a reflection of the illuminated slit from one of its faces. This thought was scarcely more than momentary; then the true interpretation flashed upon me. The light of the nebula was monochromatic, and so, unlike any other light I had as yet subjected to prismatic examination, could not be extended out to form a complete spectrum. After passing through the two prisms it remained concentrated into a single bright line. The riddle of the nebulae was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas."

Thus was confirmed an inference of Sir William Herschel, expressed toward the end of the eighteenth century. His extensive observations of the nebulae had led him to regard them as regions of fiery mist, out of which the stars may

have been formed: "A shining fluid of a nature unknown to us. . . . What a field of novelty is here opened to our conceptions! . . . We may now explain that very extensive nebulosity, expanded over more than sixty degrees of the heavens, about the constellation of Orion; a luminous matter accounting much better for it than clustering stars at a distance. . . ."

More than sixty years have elapsed since Huggins discovered "nebulium." In 1868, Lockyer discovered another light gas, helium, in the atmosphere of the sun, and nearly thirty years later Ramsey extracted it from cleveite. Now it is produced in quantities from certain deposits of natural gas and used in dirigibles. "Nebulium," far more elusive, escaped all laboratory attacks until its true nature was revealed by the brilliant work of Bowen at the Norman Bridge Laboratory of Physics in Pasadena.

Since the first observations of Huggins, many new lines, due to hydrogen, helium, carbon, nitrogen and oxygen, have been found in spectra of nebulae. From the character of these elements, it appeared certain that the gas responsible for the lines seen by Huggins must also be of low atomic weight. Our present knowledge of atomic structure shows that no such unknown element can exist. How shall we solve the puzzle?

It has recently been obvious to physicists that, in Russell's words, "the unknown lines must be due not to atoms of unknown kinds but to atoms of known kinds shining under unfamiliar conditions."

Bowen, fresh from his long series of investigations with Millikan on "stripped atoms," and skilled in the use of the powerful methods of attack developed in modern spectros-

copy, saw that a new type of radiation, marked by emission of "forbidden lines," might be possible in gases at extremely low density, pointed to by Russell as the most probable determining factor in the nebulae.

In our laboratories the average interval between the collisions of a given atom with other atoms or with the walls of the vacuum tube can never exceed one thousandth of a second, even under the most perfect conditions. In the nebulae the atoms are so far apart that the mean time between impacts is estimated to be from 10,000 to 10,000,000 seconds.

Thus in these long intervals matter in a metastable state (which in a vacuum tube is reduced to a lower state by collisions with neighboring atoms without revealing its characteristic infrequent emissions) will be free to show its existence. By methods soon to be explained in the *Astrophysical Journal*, Bowen has been able to attribute many of the unknown lines in the nebulae to electron jumps in highly ionized atoms of oxygen and nitrogen.

This discovery is of the greatest importance to astrophysics, as it explains many puzzling phenomena of the planetary nebulae and shows that the surface temperatures of the central stars that excite their radiation must be at least 100,000° Centigrade. Its bearing on the problem of the nature of matter is still more important.

Curiously enough, this discovery leads to the conclusion that great industrial corporations whose progress depends upon knowledge of the true nature of matter and its possible transformations may profit materially by astrophysical research. Indeed, if a far-sighted industrial laboratory could not obtain the results of astrophysical research from other institutions, it would be amply warranted in operating

a telescope powerful enough to utilize the unique conditions existing in the laboratories of the sun and stars.

Bowen's discovery reveals matter far rarer than any we can study on earth while Adams's investigation of the close companion of Sirius attains the other extreme, by demonstrating the existence of matter thousands of times denser than platinum, the densest known terrestial element.

Many other fundamental experiments beyond the range of our laboratories are being performed for us in the heavens,* where the powerful instruments of modern observatories have revealed them and led to their interpretation. Thus astrophysical research contributes on the one hand to our understanding of the universe, and on the other to the fundamental knowledge of the nature of matter, upon which the progress of many industries depends.

Contributed by George Ellery Hale, Honorary Director of the Mount Wilson Observatory of the Carnegie Institution of Washington, Pasadena, California.

WEALTH FROM CORNSTALKS

Many Products Possible from Agricultural Wastes

O. R. SWEENEY

After the farmer has husked and shelled the corn to feed man and beast and has let the cattle and hogs eat what they will of the cornstalks, there remain each year in the great

* See the chapter "Cosmic Crucibles" in "The New Heavens," and an article entitled "The Sun as a Research Laboratory" in the Journal of the Franklin Institute for July 1927.

American "corn belt" two hundred million tons of stalks and twenty million tons of cobs. Can this great agricultural waste be put to use?

Chemist and engineer have been working on this problem for years. It now begins to appear feasible to put these raw materials to use on a large scale within a decade or two and thus in time increase the gross annual income of the corn growers by a billion dollars. Industrial processes will add new values and the numerous useful products (some three hundred now seem possible), would further increase the national wealth. It is a prize worth a lot of effort.

Before these many products of promising usefulness could be made even on a small scale in the laboratory, years had to be spent in patient, ingenious, fundamental researches to determine the exact chemical and physical natures of these raw materials and their constituents. Not only agricultural, but also industrial and economic problems had to be solved with the aid of engineering research, supplementing the work of the scientist. Much remains to be done.

Iowa State College, in the midst of the corn belt, has been a leader in the attack. Knowledge being gotten in the cornfield will be useful also to growers of other grains, peanuts, flax and cotton, who have similar waste materials. Civilized men will be able to continue to feed and clothe the increasing populace and to supply many of their other wants by successful solution of just these problems.

What does the laboratory offer to industry from these raw materials now wasted? Paper of several grades, papier mache, wallboard and other substitutes for building lumber, substitutes for hard woods used in furniture and finish, rayon, acetic acid, acetone, a sugar that can be used by

diabetics, maple sugar flavoring to be combined with cane or beet sugar to make "maple syrup," oxalic acid, plastic materials, electrical and heat insulation, and furfural.

Furfural was a laboratory chemical not many years ago, scarce at $50 a pound. Now it is produced in large quantities at 14 cents. With increasing production, improved methods and development of co-products, even the latter price may be more than cut in half. Furfural is a fluid heavier than water, having many and various uses in plastics, dyes, paint removers, antiseptics, anesthetics, germicides, embalming fluids and motor fuels. It burns in lamps with a more brilliant flame than kerosene and has not the unpleasant odor of the latter.

If the chemist and engineer and farmer can solve the economic problems, new industries may dot the prairies. Among these problems one of the foremost has been the cheap collection of the stalks and cobs to a few places where they will be subjected to the first steps toward becoming saleable commodities. Special machines have been devised for gathering up the cornstalks on the field, or for cutting the standing corn, husking the ears and shredding the stalks. Another problem is the safe and inexpensive storage of the raw materials throughout the year, in order that the industrial operations may be continuous.

As contrasted with forests, which, once cut, are not quickly replaced, and commonly in America are not replaced at all, the corn wastes would be produced year after year in great quantities within the same areas. As nearby forests have been consumed, for example, the saw mills and pulp mills have had to move to more and more remote locations from their markets.

Lest the corn production should decrease, the fertility of the soil must be maintained. It has been learned that this can readily be done by growing soya beans as the "rotation" crop. The soya bean is a strong nitrifier of the soil. After extracting the oil from the bean, the refuse, including the stalks and meal, can be plowed back into the soil. The income from the oil, which has many uses, will partially offset the lack of income from corn in the years of change of crop. Thus the cycle would become complete by the chemistry of nature, and the energy of the sun would be converted perennially to many uses of man.

Depletion of forests and of mineral resources and advances in chemistry and engineering will have much to do with the measures of success which may be achieved in turning these agricultural wastes into wealth. At best, it will take much time, research and development.

More than research and engineering and industrial development and financing will be required. Useful and valuable new commodities may be produced, but successful production at a fair price may not bring economic success. As has well been said: The fight for recognition for a new product is almost as hard to wage as is the fight for a new idea.

See also Research Narrative No. 89, September 15, 1924, and bulletins of Iowa State College.

Contributed by O. R. Sweeney, Professor of Chemical Engineering, Iowa State College, Ames, Iowa.

GRID GLOW TUBES

New Controls of Energy

S. M. KINTNER

Vacuum tubes of various kinds have been introduced to our households in radio sets. Dentist and surgeon have made us acquainted with another kind in their X-ray examinations. In our daily work many of us use still other forms for a variety of purposes. New kinds, besides new forms and new applications, are being devised from time to time in research laboratories.

Vacuum tubes are used in large numbers to convert alternating current to direct current or direct to alternating. In radio and some other applications vacuum tubes amplify the sound or other effect being conveyed by bringing into action a much more powerful current. By adaptation and discovery researchers are developing astonishing and convenient means for control of energy through utilization of vacuum tubes.

Not very long ago, while engaged in the development of a regulating tube that would not permit the voltage in an electric circuit to exceed a predetermined amount, it was observed that the voltage at which certain tubes operated varied with the day. On bright days this voltage was lower than on dull days.

An investigation revealed the fact that some of the materials in these tubes possessed photo-electric properties. In other words, it was found that if a voltage (electric pressure) was applied to the two terminals of the tube, no current would pass while the tube was kept in darkness, but when the

tube was exposed to light it passed a small current. If the light was made sufficiently intense, the amount of current passed would ionize the small quantity of gas in the tube and thus permit the passage of a comparatively large current, enough to operate a sturdy relay.

Of course, the effect will be produced whether a light is turned on, or the tube moved into strong light, or a screen removed from between the tube and the source of light. Here then is another means for control of energy without making physical contacts. For contactless relays numerous possibilities will arise at once in the minds of readers familiar with modern mechanical and electrical equipment.

Following up the study of phenomena involved in the foregoing experience, D. D. Knowles, the inventor of the tube just mentioned, found it possible to add to the tube in a particular way another electrode so as to secure quite remarkable control of the operation of the tube. This new device, the Knowles Grid Glow Tube, is similar in size and general appearance to a radio tube, but differs principally in not having a heated electrode and in containing a gas.

When a voltage of about 400 is impressed between its anode and cathode (formerly called positive and negative poles), and the grid is left disconnected, no current will pass as the grid accumulates a charge from some of the free electrons and blocks operation of the tube. If, however, the charge be removed from the grid, the tube passes sufficient current to operate a relay, which in turn will close or open a circuit that can be made to operate any suitable electrical device.

If an alternating current be used, the grid can be discharged

by means of a small condenser. The condenser may be formed of a sheet of metal connected to the grid, as one of the two necessary plates, and a human hand as the other. The energy in the operating circuit is approximately a hundred million times that in the control circuit, which is to say that the tube multiplies by that large number. The usual relay has a corresponding ratio of 1 to 10,000. This tube gives the greatest amplification thus far developed.

It was by means of such a grid glow tube that the late Elbert H. Gary, as Chairman of the Board of the United States Steel Corporation, in his office in New York, by a motion of his hand, started the new electrically operated mills of the Homestead Steel Works, near Pittsburgh, about 400 miles distant. In this instance, the tube controlled a radio transmitter whose signal was picked up in Homestead and on being amplified, actuated the relay that closed the power circuit and started the great mills.

Contributed by S. M. Kintner, Manager, Research Department, Westinghouse Electric & Manufacturing Company, Pittsburgh, Pennsylvania.

EXPLODING WOOD

Making Pulp by a New Method

W. H. MASON

Several years ago I was perfecting a process for extracting rosin and turpentine from Southern pine boards to recover these substances and raise the grade of the lumber. In traveling from one mill to another I was impressed with the great waste in slabs, edgings, board ends and sawdust,

most of which was consumed in the trash burners. To find a way to convert this wood waste into wood pulp became a fixed purpose.

Power costs for mechanical grinding are too high and the gums from the pine quickly impair the efficiency of grinding surfaces. The chemical process was unattractive because of high cost for plant, loss of nearly half the raw material in the digesters and the difficulty of treating the bark.

The problem was to separate the fibers without losing the lignin. Wood is plastic when subjected to heat and moisture, probably due to some change in the lignin. Would it be possible both to soften the lignin and to blow the fibers apart, with steam? Could one apply temperature and moisture in such manner as to soften the lignin more than the cellulose fibers without injury to the fibers, and create a pressure within the wood sufficient to disrupt the fibers upon the instantaneous removal of the surrounding pressure?

In 1924, I set up an experimental plant in a shed next to a sawmill at Laurel, Mississippi. My first steam gun was a piece of old steel shafting about three inches in diameter and fifteen inches long with a hole bored into it from one end and enlarged inside to twice the diameter of the entrance. Through one side a small opening was drilled and a brass cup for holding oil secured in it so that temperatures inside the gun could be taken with a thermometer. The outside of the gun muzzle was tapered to a ground valve joint. The valve, closing the gun, was held in place by a pin, supported by a yoke surrounding the gun and bolted to its breech.

The gun was filled with chips and water, and closed. Then two gasoline torches were directed against its side until

the temperature inside rose to 480° Fahrenheit, indicating a pressure of approximately six hundred pounds per square inch. A four-foot bar was placed with one end against the pin. A smart blow with a hammer on the other end of the bar knocked the pin loose and allowed the valve to blow out.

The first experiment completely reduced the chips to fiber, but it took a long time to find the valve. The principle of steam explosion of wood had been demonstrated. Further experiments were needed to determine the best steam pressures, temperatures and time intervals. For weeks this crude gun was used with different kinds of wood,—varying pressure, temperature and time.

Subsequently, two other experimental guns were constructed, in which pressures as great as nine hundred pounds were used. It was learned that time was as important as steam pressure and temperature. Present practice is to subject the chips to a low pressure of two hundred pounds for ten to fifteen seconds and then to a pressure of one thousand pounds for three to five seconds before blowing them from the gun.

Naturally we hoped to make paper from this pulp, but have not yet produced a satisfactory quality and therefore turned our attention to other possibilities.

The exploded pulp was found especially suitable for the manufacture of insulating boards for a large variety of uses. In a beater made out of an old gear, and some angle irons for a bed-plate, the fiber was worked over, formed into a board by hand, compressed to one-third volume in an old letter press, and dried in an oven. By further experimentation processes for production of the insulating board were perfected. It was named Masonite.

For making another product a hydraulic jack was tried, using pressures as high as five thousand pounds per square inch to compress the pulp; but the resulting board, although fairly hard, had no characteristics out of the ordinary and so the experiments were temporarily abandoned.

Later we found a steamheated press and one morning put some insulating board in it for further compression, shut off the steam, went about other work and forgot it until after dinner. Then we found the press hot because of a leak in the steam valve. Upon opening the press we were surprised to find a hard, dense board stuck to the felts, possessing unusual qualities.

Four months of experimentation developed processes for producing boards with hard dense surfaces and porous, insulating interiors, which we called Presdwood. It is very dense, stiff and hard, and has a tensile strength in any direction of four thousand to five thousand pounds per square inch. It comes from the press with one side polished and can take any finish that can be applied to ordinary wood. Many uses are being found for Presdwood.

Further research and experience may develop possibilities still unsuspected for this process for producing wood pulp from wood waste.

. Contributed by W. H. Mason, Member, American Society of Mechanical Engineers, Vice-President and General Manager, Mason Fibre Company, Laurel, Mississippi.

ICE

Relief From Its Damage

HOWARD T. BARNES

For a reasonable expenditure the menace of icebergs can be removed from the North Atlantic steamer route. Also by skilful engineering utilization of physical researches extending over thirty-five years, the great expense caused by ice at power plants, bridges and many other structures and the damage from floods caused by ice dams, or jams, can be greatly reduced.

Ice can be broken up by blasting, or reduced to liquid water by heat, or disintegrated by the aid of chemicals. Quick-acting, sure, powerful, inexpensive methods are required. To supply artificially enough heat to melt a berg or a jam is both physically and financially far beyond the range of feasibility. Skilful, limited applications of heat will, however, accomplish much.

Since 1893, the writer has been making scientific researches into the physical properties of ice and useful methods of controlling it so as to reduce the great toll which it levies upon humanity each year.

One of his discoveries was that thermit could be used effectively at modest cost. Thermit is a mixture of finely powdered aluminum metal and oxide of iron. When properly ignited, thermit reacts vigorously, generating very high temperatures and producing extremely hot liquid steel. Many of our readers have seen thermit in action in city streets, where rail joints of a trolley line were being welded, or in manufacturing plants.

The energy from this molten steel supplies rays that equal or surpass those of the sun in power to penetrate ice for many feet. The action of the white-hot steel upon the ice is remarkable, converting it into hydrogen and oxygen gases so rapidly that a powerful explosion results. Thermit itself is not explosive and can be handled safely.

In addition to disruption by the explosion, the water currents are restored to their original channels and continue to wash away the ice weakened by the heat rays and explosion. In this way a huge jam may readily be broken up so that it will float piecemeal harmlessly down the river, or an iceberg be split into fragments so small as to be no menace to commerce.

In February, 1925, for the first time, an ice jam was treated by this radiant heat method. On that occasion 250,000 tons of ice at Waddington, New York, in the St. Lawrence river, moved out in a few hours after the reaction of three thermit charges of ninety pounds each. A jam at Ogdensburg, New York, containing a million tons of ice, was removed in nine hours with two ninety-pound charges of thermit.

A jam 8,500 square feet in area, nine feet thick, was lifted off a shoal at Morrisburg, Ontario, and broken up by one charge of ninety pounds. Similar operations have been successfully carried through, including the removal, without damage, in ten days, of a dry jam twenty-five miles long at Oil City and Franklin, Pennsylvania. The City of Belleville, Ontario, on the Moira River was protected from a severe flood last winter by thermit and calcium chloride.

In 1910, I sent out my first expedition to study icebergs. Others followed. In 1924, I observed that water from sur-

face melting flowed all the daylight hours on an iceberg, maintaining a surface temperature at the freezing point. During the night, the water froze. The greatest cracking of the ice and breaking off of fragments occurred early in the morning and immediately after sunrise. These observations prompted the thought that strains could be set up at will in a great ice mass by local applications of heat at a high enough temperature to cast powerful rays into the ice.

The first tests were made in 1926. One berg treated was approximately five hundred feet square at water level, with cliffs rising on one side seventy-five to one hundred feet. A hole was bored into it about three feet and charged with one hundred pounds of thermit. When this charge was fired, flames shot upward one hundred and twenty-five feet and the explosion threw off great masses of ice.

The intense heat in direct contact with the hard ice sent a temperature wave into the mass which caused a great deal of cracking and visible disruption. This cracking went on all evening. Toward morning there was a very loud report. Later in the day we found the great bulk of the interior had come away. The day following revealed the full effect of the cracking, for the whole plateau in which the charge had been placed split and broke away, almost across the thermit hole. Approximately a third of the ice was split off. Had we placed a few more charges, the whole berg would have been broken up. Sinking the charges deeper into the ice, as could easily be done, would have increased their effectiveness.

Sodium chloride, calcium chloride, calcium carbide, crude sulphuric acid and hydrochloric acid, all may be effectively used in rotting and destroying ice. Cinders, sand and gravel

also are useful, when correctly applied, with a little calcium chloride, to draw the sun's heat and aid in the rapid destruction of surface ice. More experimentation is needed, but rational ice engineering now has a scientific basis.

Contributed by Howard T. Barnes, D.Sc., F.R.S., Professor and former Director of Physics, McGill University, Montreal, Canada.

BERYLLIUM

Hardest and Most Inert of the Light Metals

HUGH S. COOPER

Who can measure the impetus given to intellectual and spiritual progress and the wealth created by chemist, physicist, metallurgist and engineer through discovery and development of a new metal? Recall aluminum, familiar in every household, and tungsten, glowing in every Mazda lamp and adding to the toughness of steel.

Beryllium may soon be as commonly known, although its progress has been very slow. In 1922, it sold at the rate of $5,000 per pound, but only a few *grams* could have been purchased, even at this super-platinum price—witness to the difficulties of purifying it by any means available to chemists and metallurgists until recently.

The high cost, indeed, seemed a metaphysical corollary to the close relationship of beryllium to the gems, aquamarine and emerald, special forms of beryl, long prized. Cleopatra's emerald mines in upper Egypt were worked as early as 1650 B. C. Beryl was one of the gems in the breastplate of the Hebrew high priest and one of the

beautiful stones the Apostle John beheld in the foundation of new Jerusalem in his vision recorded in the Book of Revelation.

In its less beautiful forms Beryl, which is the best source of the metal, is still sent to waste heaps of feldspar mines of New Hampshire. Large deposits are known also in other states and several foreign countries. Beryllium oxide, the starting point for making the metal, constitutes about 14 per cent of beryl, chemically a double meta-silicate of aluminum and beryllium.

Pliny, the Roman historian, A. D. 23–79, expressed the opinion that beryl and emeralds were the same kind of mineral. Seventeen centuries passed before Vauquelin, a French chemist, established their chemical identity, and in the process discovered in them a new oxide. He was unable to reduce this oxide and thereby obtain the metal, to which the name, beryllium, from the Greek, was later given.

Possibly "beryl" is derived from a Sanskrit word meaning crystal, and is the forefather of "brilliant." Specimens of beryl free from coloring matter and flaws are transparent. Another name suggested was glucinum, or glucinium (still used by some chemists, particularly in France), because its salts are sweet. Its nitrate is used for impregnating mantles for gas lights.

In 1828, Wöhler, the German scientist, separated a little of the metal in an impure state, as did others about the same time. The total quantity in the world until recently was hardly sufficient for determinations of its physical characteristics and its industrial possibilities.

In 1916, the author, believing that beryllium could be obtained in large quantities, that its price could be brought

to levels that would permit use and that its characteristics would help to solve many problems of industry, undertook researches that reached a successful conclusion and led to the establishment of a small pilot plant producing metallic beryllium of 99.5 per cent purity at the rate of about 150 pounds per month, refined methods permitting sale at $50 a pound.

There are good prospects that by 1931 the metal may be marketed in large quantities, perhaps at $10. Reductions will come gradually; they will depend upon further refinements of technique of operation, upon economical utilization of the large quantities of valuable by-products, and upon development of more stable sources of ore. When all these problems have met their solutions, the cost of this hitherto rare metal may well fall as low as some of those frequently considered "common."

New processes had to be evolved, new types of apparatus devised—and always that engineerig challenge: Economically. One irritating and time-consuming factor was the glaring inaccuracies that well-nigh saturate the technical literature. One man claimed to have made the metal on a commercial scale by electrolyzing a compound which does not conduct current; another patented a process which when tested, resulted in the isolation of an entirely different metal.

What is there about beryllium to make it worth this long endeavor? Its remarkable properties. In weight, only two-thirds as much as aluminum and but a little more than magnesium, it is the lightest known inert metal, being considerably less than twice as heavy as water. Scratching

glass easily, it is one of the hardest of metals, differing sharply from both aluminum and magnesium.

Its expansion and contraction with changes of temperature are almost the same as those of iron—again diverging from the other light metals. It takes a high polish, remains untarnished in the air, and is only slightly attacked by influences which take heavy toll of aluminum and magnesium. In color it is grey, resembling steel closely, and its melting point, 1285° Centigrade, also approaches that of steel. Heating to 600° Centigrade does not materially affect it.

Beryllium will probably first come into commercialization in alloys, of which the aluminum, copper, nickel, iron and silver have received most study. To aluminum, beryllium adds strength and resistance to corrosion; in iron, it acts as a powerful hardening agent; and its stiffening effect on copper is unequalled. Whatever the element to which it is added, beryllium seems invariably to transfer at least part of its own non-corrodibility.

New uses are continually being developed. One of the most interesting is pure beryllium plates for emergence windows in X-ray tubes. The lower the atomic weight of an element, the more readily will it permit the passage of X-rays; beryllium will transmit the rays seventeen times as well as the aluminum generally used hitherto.

Contributed by Hugh S. Cooper, Member, American Electrochemical Society, Laboratory Director Beryllium Corporation of America and Kemet Laboratories Company, Incorporated, Cleveland, Ohio.

STRAW INSULATING BOARD

Research Helps a New Building Material

SIDNEY D. WELLS

A man had experience in producing wall board for houses and other buildings. He believed that a board which would be a non-conductor of heat, stiff and strong would be widely used. He knew that good boards had been made from wood waste and from bagasse (sugar-cane refuse). He lived on the border of a great cereal-growing region.

In the great wheat areas enormous quantities of straw are burned annually because it is too resistant to decay to be assimilated by the soil between harvest and sowing time. Only an infinitesimal quantity is otherwise utilized. Most cereal areas are devoid of forests and must transport lumber from distant places. From the beginning of civilization straw has been used in rural habitations, for both man and beast, where the fire hazard was small. Its capacity for reducing the passage of heat has long been recognized.

Therefore, our industrial adventurer planned to make boards of straw in cereal regions where there are no forests, where atmospheric temperature ranges are large and changes sudden.

Because of its desirable qualities straw insulating board should win its way into other markets also, he reasoned, and so without further ado he organized a company, raised capital and proceeded to build a plant, guided by his knowledge of manufacture of wall board from wood waste and bagasse. He had no evidence that satisfactory boards could be made of straw—and much less that they could be produced at a commercially permissible cost.

Then our adventurer thought of laboratories and the specially trained men in them. It might be possible to find out experimentally whether insulating board could really be made from straw, what properties it might possess, what method would be most satisfactory, what machinery most suitable. Some knowledge of difficulties might be gotten, an estimate of cost of production made. Furthermore, by tests of boards produced on a small scale their virtues and limitations might be determined and information for a selling campaign had in advance.

The laboratory learned that few raw materials, if any, were as adaptable as straw to the manufacture of insulating board; its fibers are cemented together in long filaments, which can be pounded apart after softening by digestion at elevated temperatures for a few hours. The proportion of fiber is large; it is devoid of pith. Only mild cooking is required, and not more than twenty per cent is rendered soluble. Much of the latter is adhesive; it acts as a strong binder and water-proofing agent.

Board made from straw is exceptionally strong because the filamentous characteristics are retained; felting properties together with the cementing characteristics of the binding material form a strongly interwoven mass. In fabrication in the wet condition the fibrous mass is extremely flexible and plastic, but after drying, it becomes rigid and strongly cemented together.

The proportion of air cells is so large that the board weighs only 600 pounds per thousand square feet; since the board is $\frac{7}{16}$ inch thick, this is equivalent to $16\frac{1}{2}$ pounds a cubic foot. Nevertheless, it can be cut with saws or knives to

dimensions, with remarkably sharp edges. (Eastern white pine, a light wood, weighs 24 pounds a cubic foot.)

In the preparatory digestion agents may be used that render the soluble constituents not needed in the board, capable of treatment for the recovery of valuable co-products. These substances are extremely susceptible to bacterial action and under proper control acetic acid, lactic acid, various alcohols and similar products may be obtained in quantities that appear to be promising. Further work will increase the number of organic substances that can be obtained by using the proper organisms and also increase the yields. Other products can be obtained by chemical engineering methods, such as hydrolysis and destructive distillation.

Straw insulating board can be used as sheathing on the outsides of buildings or instead of lathing inside. Stucco or plaster adheres more firmly than to lath. It is a sound-deadener. Its heat insulating capacity is particularly useful in roofs of some kinds of factories. It can be painted or varnished, coated with pitch or treated in almost any other manner in which wood is treated.

It does not hold nails as well as wood, but by using nails with large heads driven into framework of suitable material a structure can be built, shown by tests to be more rigid than a building having standard one-inch wooden sheathing. It is more easily dented than wood, but when covered with plaster or stucco, resists indentation as well as plaster or stucco on metal lath. It is less readily inflammable than wood and can be made more resistant to fire by impregnation.

After modification of plans, the factory was built and is producing board $\frac{7}{16}$ inch thick, 4 feet wide, 8 to 16 feet

long. Straw insulating board can be made of any length, or any width up to 144 inches and of various thicknesses. In both old and new industries research by competent men benefits maker and user of the product.

Contributed by Sidney D. Wells, Member, American Institute of Chemical Engineers, American Chemical Society, Society of American Foresters, Technical Association of the American Pulp and Paper Industry; Director of Laboratory, Paper Mills Laboratories, Incorporated, Quincy, Illinois.

THE AIRCRAFT RADIO BEACON

Flying by Instruments

NATIONAL BUREAU OF STANDARDS

It is impossible to exaggerate the solitude and helplessness of an airplane flying in the dense fog. Deprived of all landmarks, under incessant strain to maintain equilibrium and direction, the aviator must abandon dependence upon his senses and navigate by his instruments. It is contrary to human instinct to throw overboard the testimony of the senses and stake life on an instrument. Not every pilot can do it.

One instrument tells the pilot his elevation, another whether he is turning or flying straight away, and his compass indicates his general direction. They do not tell him if he is drifting sidewise due to cross wind, nor at what speed he is traveling because the wind may slow him down or speed him up. What "instrument flying" has lacked is supplied by the radio beacon.

The beacon system will probably render its principal

service on fixed commercial airways. With the radio beacon made practical and dependable, air route operations enter a new era of regularity and safety. Most trips formerly omitted, or undertaken only at great risk, can be confidently made. Occasional fog over the landing field itself is the chief remaining obstacle.

Although the aircraft radio beacon has reached practical development only this year, its origin goes back to 1920. At the request of the War Department, the Bureau of Standards undertook to develop a directive radio system for airplane navigation.

A method was devised in which radio waves were transmitted alternately from two directive antennas placed at an angle with each other. Equality of signal intensity from the two antennas along a certain line or zone determined a course which an airplane could follow. The system was tried out successfully in Washington and in Dayton, Ohio. In succeeding years the Army engineers at Dayton developed the system further.

When the Aeronautics Branch was formed in the Department of Commerce in 1926, it determined that radio aids would be necessary on the civil airways, and assigned their development to the Bureau of Standards. The Bureau undertook to perfect the radio beacon, particularly by developing a visual indicator so that a pilot would have on his instrument board a direct indication of his location. The Department expects to install the new radio aids during the next two years. Required equipment on airplanes is reduced to a short pole antenna and a receiving set weighing a few pounds. All of the expensive and powerful apparatus necessary is on the ground, maintained by the Government.

The radio beacons operate in the frequency band 285 to 315 kilocycles, and on the telephone stations in the band 315 to 350 kilocycles. These were allocated to air service by the 1927 International Radio Convention. For the present the beacons are adjusted to the frequency of 290 kilocycles, and the telephone stations to 333 kilocycles.

The directive radio beacon is a special kind of radio station, usually located at an airport, just off the landing field. Instead of having a single antenna like an ordinary radio station, it has two loop antennas at an angle with each other. Each emits a set of waves which is directive, i.e., it is stronger in one direction than in others. When an airplane flies along the line exactly equidistant from the two beams of radio waves, it receives signals of equal intensity from the two. If the airplane gets off this line, it receives a stronger signal from one than the other.

The indicator on the airplane shows when the signals are received with equal intensity, by means of two vibrating reeds tuned to different modulating frequencies used on the two antennas. When the beacon signal is received the two reeds vibrate. The tips of these reeds are white in a dark background so that when vibrating they appear as vertical white lines. The reed on the pilot's right is tuned to a frequency of 65 cycles and the one on the left to 85 cycles.

It is only necessary for the pilot to watch the lines. If they are equal in length, he is on his correct course. If the one on his right becomes longer, the airplane has drifted off the course to the right. If it drifts off the course to the left, the white line on the left becomes longer.

Successful flights have been made up to 135 miles, in fog and over hazardous mountain terrain. This distance is

GEORGE K. BURGESS

more than enough to demonstrate the success of the system, as it is contemplated that beacon stations will be placed not over 200 miles apart, with a straight airway between them. They will be supplemented by small marker beacons at intervals. A characteristic signal from a marker beacon will show on the visual indicator aboard the airplane what point is being flown over.

The receiving system is little affected by interference, including engine ignition interference, which has hitherto been the bar to satisfactory use of radio on airplanes.

With the beacon stations in operation throughout the country, airplanes in flight will always have the beacon signals available to keep them constantly informed of their locations. Indeed, when a pilot leaves his regular course either accidentally or to avoid a stormy area, the beacon indicator shows him the way back.

Contributed by the National Bureau of Standards, of the Department of Commerce, Dr. George K. Burgess, Director.

ELECTRICAL PROSPECTING

Locating Electrically Conductive Ores

J. J. JAKOSKY

Mining supplies raw materials for many manufactures of great total value. Unlike vegetable and animal raw materials, ores cannot be grown. Man simply can hunt for the ore bodies which exist in the earth.

Surface indications have been the principal dependence for centuries, but necessity is spurring the development of new

methods of prospecting which will carry the search beneath the surface. They must be reliable, rapid and inexpensive. Magnetic, gravitational, seismic and electrical methods have been developed as the intelligence of modern mining has turned from divining rods and doodle bugs to physical science.

Research in connection with low and high frequency electromagnetic induction and radio amplifying devices has resulted in obtaining new means for geophysical prospecting. Electromagnetic induction has been made the basis of a method to which the name Radiore has been given.

Development of the Radiore process began with an investigation by A. B. Menefee and H. E. Olund, mining engineers, of a so-called "radio" method for locating ores. These original tests were conducted at Darwin, California, near the famous Death Valley. The characteristics of the ore occurrence in this locality were well known to Menefee and Olund, who were in charge of the mining operations for large interests. The results of the radio method were encouraging, but many of the data could not be interpreted to agree with known ore occurrence in tunnels and other mine workings.

A program of research and development was then formulated. E. H. Guilford, Captain in Radio Communication of the U. S. Army, and J. J. Jakosky, Consulting Electrical Engineer, were added to the technical staff. The original radio "antenna" system for energizing the ore was replaced, as a result of the research, by a loop or coil system, which together with a decrease in the frequency and the development of a new direction-finding equipment has resulted in the present Radiore method, having many possibilities.

This method has functioned practically as well in swampy country as in deserts. Snow and ice are no bar to efficient work and the character of the surface soil is unimportant. Territory covered with lava or float, or where no outcrops occur, can be as readily surveyed as other kinds,—all because no contact with the ground or ore-body is employed.

An alternating current is caused to flow in an "energizer" on the surface, similar to a small radio transmitter with a coil antenna. This current creates an electromagnetic "field," as electrical people say, which causes currents to flow by induction in conductors underground. The induction principle has become familiar by use for many years in a variety of electrical equipment.

Many ores of metals are better conductors than other rocks and earths. The quantity and character of the current induced are markedly affected, therefore, by the presence of an ore body, and depend upon the type of ore, the "frequency" of the current in the energizer, the relative conductivity of the substances at and below the surface of the ground, and the current distribution.

Frequency is of especial importance when the ore encountered is disseminated, broken or faulted,—to use the geologist's words. High frequencies are employed, 40,000 cycles a second being common, because an appreciable current can be caused to flow through such ores merely by using a sufficiently high frequency.

Unless the ore is about one hundred times as good a conductor as the surrounding earth no electrical method gives clear indications. Such a degree of difference is common, and it is not uncommon to find ores 10,000 times as good conductors as the earth.

When a current is flowing in a conductor, the conductor is surrounded by an electromagnetic "field," a most important characteristic of which is that unlike an electric current it readily passes through very poor conductors such as rock and earth. The chief operation is locating the conductor (the ore) by determining upon the surface, the direction from which this field comes.

A vacuum-tube detecting and amplifying apparatus and a "direction-finding" coil of special design are used, not dissimilar to equipment in shore radio stations for determining positions of ships at sea, but the coil is pivoted on a horizontal axis, and works in a vertical plane. By moving the coil and noting the changes of the "signal" in the receiver the direction of the ore body from the apparatus can be determined. The differences of speed of the electromagnetic waves through air, earth and ore, and other electric and magnetic effects, however, cause complications, demanding skill and experience in operating.

Research for additional fundamental data is being continued and with the aid of new facts improvements are being made. Points on the surface of the ground directly above the ore body can now be located with considerable accuracy. Accuracy of depth indications for ores whose depths do not exceed 250 feet is generally within ten per cent, which is sufficient for ordinary mining purposes.

Results in the United States and Canada for two years have proved the general utility of the inductive, or electromagnetic, process of prospecting, but it will not render the professional mining engineer or geologist of minor importance. On the contrary, it is a highly scientific tool for him

and may eventually greatly decrease the speculation in prospecting and mining.

Contributed by J. J. Jakosky, Consulting Engineer in charge of Research and Development, The Radiore Company, Los Angeles, California.

VENTILATING VEHICULAR TUNNELS

The Holland Tunnels

A. C. FIELDNER

Thousands of persons motor daily between New Jersey and New York through the famous Holland Tunnels under the Hudson River. When these tunnels were proposed, many engineers doubted whether it would be possible to render them safe for passenger traffic. Research has solved the problems.

Exhaust gases from automobiles contain from one to fifteen per cent of carbon monoxide, varying with operating conditions. This gas, a deadly poison, has no color, taste or smell, and is nearly of the same weight as air. The commissions of the States of New York and New Jersey coöperated with the U. S. Bureau of Mines in research on: 1, quantity and composition of exhaust gases from motor vehicles under tunnel conditions; 2, maximum percentage of carbon monoxide permissible in tunnel atmosphere; 3, power required to move the air demanded for adequate ventilation; 4, best method of introducing and removing the ventilating air; 5, sizes and positions of the ventilating, ducts.

To obtain information on quantity and composition, the

Bureau, at its Pittsburgh Experiment Station, made tests on 101 passenger cars and trucks of various capacities taken from service, without adjustment, so that the gases were representative of actual operating conditions. An accurately graduated tube containing the gasoline to be used was attached to each carburetor.

Apparatus for collecting the gas sample was attached to each exhaust pipe. Each car was run over a one-mile course at speeds of 6, 10 and 15 miles per hour. Another course having a 3 per cent grade was also used. Tests were made with engines racing, idling and accelerating, imitating conditions in the tunnel when crowded with cars starting after a blockade.

Research to determine the maximum allowable percentage of carbon monoxide was conducted by Professor Yandell Henderson, consulting physiologist, Bureau of Mines, at the Physiological Laboratory of Yale Medical School. Animals were subjected to synthetic atmospheres containing 1 to 10 parts per 10,000 parts of air, and later Dr. Henderson and his associates subjected themselves and students at Yale University to these tests.

The physiologists concluded that if the carbon monoxide were not allowed to exceed 4 parts to 10,000 parts of air, there would be no noticeable effects from exposures not exceeding one hour. With knowledge of the quantity given off by various types of automobiles and trucks and an estimate of the maximum vehicular capacity of the tunnel, it was possible for the engineers to compute how much carbon monoxide must be removed to maintain the required standard.

To determine the flow of air and the power required to

move the air in ducts and openings such as would be used in the tunnel, a half-sized duct 300 feet long, and full-sized elbows of several patterns were built at the University of Illinois Engineering Experiment Station.

The final check was obtained by building a model tunnel at the experimental mine of the Bureau of Mines, at Bruceton, near Pittsburgh, having ducts similar to those proposed for the Holland Tunnels, and an axial length of 400 feet; it was approximately 9 feet wide and 8 feet high. Above the ceiling was an air duct 3 feet high, and below the floor another 2½ feet high. Either duct could be used for introducing fresh air, or for exhausting contaminated air.

The tunnel was sufficiently large to accommodate small five-passenger cars. It was equipped with sensitive apparatus for measuring temperature, humidity, quantity, velocity and pressure of the air; 48 air-sampling tubes were installed on eight cross-sections, to obtain samples for chemical analysis, and to determine the diffusion and concentration of the exhaust gases with different method of ventilation.

In these tests 10 cars were spaced at 40-foot intervals and operated at a speed of 10 miles. Tests were made with various methods of introducing fresh air and removing the contaminated air. Each driver and observer was subjected to physiological examinations before and after the tests. The actual quantity of carbon monoxide absorbed by each person was determined by examining a few drops of blood drawn immediately after the test.

Introduction of fresh air at the bottom of the tunnel and removal of foul air at the top was more efficient than the reverse. The chemical and engineering sciences enabled the designing engineers to calculate their ventilating system

with great accuracy. After its completion, tests of tunnel atmosphere showed results exactly as predicted.

Important factors in maintaining adequate ventilation are automatic carbon monoxide recording machines invented by the staff of the Pittsburgh Experiment Station for the Holland Tunnels. They continuously record on a chart the quantity of carbon monoxide in the tunnel atmosphere, and are sensitive to within $\frac{1}{10,000}$th of a per cent. If the concentration exceeds four parts in 10,000 parts of air, the machine automatically rings a bell and flashes a danger light in the control room, where immediate measures may be taken to increase the air circulation.

Results of this pioneering research have been useful in the ventilation design of other tunnels, particularly the Liberty Tunnel, at Pittsburgh, Pennsylvania, and a tunnel under the estuary between Oakland and Alameda, California. The physiological researches on the effect of carbon monoxide on human beings have also proven of immeasurable value in industries where carbon monoxide is frequently met.

Contributed by A. C. Fieldner, Member, American Institute of Mining and Metallurgical Engineers, Chief Engineer, Experiment Stations Division, U. S. Bureau of Mines, Washington, D. C.

ONE BILLIONTH OF AN INCH

Measured by New Optical Method in Photoelectric Research

BELL TELEPHONE LABORATORIES

Conquest of space by the astronomer has its counterpart among the problems of the physicist in the laboratory. In the solution of a problem in photoelectricity, carried out in the Research Department of the Bell Telephone Laboratories, measurement of distances down to one billionth of an inch had to be made. The method of measurement used is revealed in the description of how the photoelectric efficiency of very thin films of rubidium was studied.

Imagine this sheet of paper split into a thousand sheets, and then imagine one of those very thin sheets again split into three thousand sheets; then, one of the extremely thin sheets would represent the thickness of a metallic film measured by this method. Or imagine that the wall of an average soap bubble could be cut into forty thousand layers; then one of those layers would have that same thickness.

Some recent developments in the art of communication, such as telephotography, talking motion pictures, and television, have as an essential part a photoelectric cell whose function is to yield an electric current faithfully proportional to the amount of light falling upon it. Various adaptations of the photoelectric cell of course require different characteristics. These have been carefully studied and already applied to many uses by the Bell Telephone Laboratories.

It had long been noticed that alkali metals when in the form of thin films were more efficient in yielding photoelectric currents than when in bulk. It was, therefore, desired to know more about the relation of film thickness and photoelectric response.

Of the commonly used alkali metals, which include sodium, potassium, rubidium and caesium, rubidium lends itself best to the study of thin films. It volatilizes, diffuses and deposits in vacuo at conveniently low temperatures, and in short time intervals suitable for experimental purposes.

For the study of the phenomena involved, there was constructed a large vacuum cell containing enough rubidium to allow a spontaneous deposit to take place on all internal surfaces until equilibrium at room temperature had been reached.

This deposit, so thin that it was quite invisible, covered not only the walls but a thin square piece of black glass as well. Supporting this plate at opposite ends were platinum wires, sealed onto the front surface to make contact with the metal film. A tungsten filament, supported close behind the plate, provided radiant heat for driving off the rubidium whenever desired. The photoelectric current was collected on a large nickel anode which nearly enclosed the glass plate and filament, and an area of the cell wall was kept clean with a flame to provide a window for light to pass through to the plate.

Two series of measurements were required to find the relationship between film thickness and photoelectric response—one while the thickness was diminishing from that of a heavy, driven-on, opaque coating down to the equilibrium value (the amount tending to remain on the plate at

room temperature), and the other while the rubidium was depositing on the freshly cleaned glass plate. During each process, the electrical conductivity along the surface of the glass plate was being measured. This approached the same value regardless of the direction from which the equilibrium point was approached. The question then became: "How thick is the film at its equilibrium value?"

Here is where a new method of measurement had to be adopted surpassing in fineness not only the highest power microscope but the interferometer* as well. The measurement must reach the hitherto inaccessible region between visible light and X-rays, radiations whose wave-lengths bear to each other roughly the ratio of ten thousand to one.

It seemed likely that the thickness of the film to be measured would be as little as one atomic diameter, which for rubidium is one-half of one millionth of a millimeter. Waves of light convenient to work with are a thousand times as great as that in length.

It was decided therefore to base the measurements of thickness on the principle that plane-polarized† light in passing through any film, experiences a rotation of its plane of polarization. The extent of the rotation is governed by the thickness of the film, the wave-length of the light and the angle of incidence.

By using light of a single wave-length (the green line of the mercury arc spectrum was chosen), and taking a set of observations at different angles of incidence with a polariza-

* An apparatus for measuring very small distances by the aid of lines caused by the interference of waves of light.

† Light passed through a crystal so as to put its waves, or vibrations all in one plane.

tion spectrometer, we were able to obtain accurate values of the thickness of the rubidium film from the known constants of the material. This was possible not only at the equilibrium condition, but while the film was growing or diminishing. By interspersing optical and electrical measurements, we were able to find the rate at which the film increased or diminished in thickness.

A practical necessity in laboratory work thus became the occasion for creating means for measuring accurately the thickness of films so inconceivably thin as one billionth of an inch.

Contributed by Bell Telephone Laboratories, New York, Dr. Frank B. Jewett, President, Dr. Edward B. Craft, Executive Vice-President.

CHROMIUM

A Helper of Iron in Service to Man

FRED M. BECKET

Chromium, known as a chemical element since discovery by Vauquelin about 1800, was but little used until after 1827. Then a young man named Tyson, who had had experience with a British metallurgical company, noticed while in the Farmers' Market of Baltimore, Maryland, a farmer who had propped his cider barrel with chunks of black mineral which Tyson recognized as chromite.

Inquiry led him to the finding of this ore in northern Maryland and in Pennsylvania. With the financial assistance of his father he organized the chromite industry of the Maryland-Pennsylvania district. For nearly fifty years they dominated the world supply. In those days, chromium

was used largely for making chemicals which by their brilliant colors gave the element its name, from chroma, Greek for color.

For sixty years, research was conducted by Europeans, but they made no metallurgical use of chromium although recognizing its hardness and its resistance to tarnish, to oxidation when heated and to many acids. About 1869, the Chrome Steel Company, of Brooklyn, started producing ferro-chromium by carbon reduction in crucibles and making chrome steel therefrom.

In 1877, Brustlein began large scale manufacture of chromium steel in France by a similar method. Shortly thereafter another French works began to make ferro-chromium in the blast furnace. In 1892, Sir Robert Hadfield published his classical paper, which gave fresh impetus to research. About this time Osmond, Arnold, Le Chatelier, Roberts-Austen and others were laying the foundations of the metallographic theory of steel, particularly of alloy steels.

Among the first conspicuous uses of chromium in steel was that for the Eads Mississippi River bridge at St. Louis, completed in 1874. Development of chromium steels and other alloy steels was greatly retarded until the metallurgical industries came to appreciate the need for research.

In 1896, at Spray, North Carolina, De Chalmot produced ferro-chromium in the electric furnace. In 1897, commercial production by this method was begun at Holcomb Rock, Virginia. Soon the reduction of chromium by fuel heat everywhere gave place to electric smelting, the high temperature of which enabled production of alloy richer in chromium, more uniform of content, and lower in cost. Carbon content of about 6 per cent was too high for some

steels. Ferro-chromium lower and still lower in carbon was demanded until now much of this alloy contains less than 0.10 per cent of carbon.

Even below 1 per cent chromium confers strength, hardness, and resistance to abrasion. Such steels are most usual in ball and roller bearings, case-hardened gears, and mining and milling machinery subjected to hard duty.

Nickel, vanadium and molybdenum often participate in low-chromium steels special to the automobile—materials which successfully resist terrific strains imposed by a hard-driving public. High-speed tool steels which have made possible the fine automobile at low cost draw their fast-cutting durability from the indispensable association of chromium with tungsten.

Stainless steels and the technique of making them were discovered in England about 15 years ago through Brearley's researches. They resist corrosion by the atmosphere and by mild acidity, and retain the mechanical properties expected in a steel for everyday use.

Rustless irons resemble stainless steels in chromium content, but by reason of the intentionally low carbon are soft. Their formability permits use in nitric acid plants, in seamless tubing for thermal "cracking" processes, and in steam turbine blades.

Chromium imparts to steel greater toughness, a vital property; strength and hardness alone do not protect against breakage under the shocks to which modern high-speed machinery is subjected.

Chromium and ferro-chromium, its principal commercial form, are not commonly known to the public, although essential constituents of a vast number of metal products in daily

use; for examples, heating wires in electric toasters, waffle-irons, stainless-steel cutlery, chromium-plated kitchen and bathroom fixtures.

Retention of strength and resistance to oxidation at high temperature make chromium-nickel alloy useful also for other household and many industrial electric-heating devices. With sufficient chromium, certain alloys become very resistant to many sorts of chemical attack. The greatest economic service of such metals is in dairies, chemical plants, and apparatus which must resist corrosion and avoid contamination of products.

Accident accompanied by keen observation account for American discovery and development of chromium ore, but not for technical results in application. These have come from years of intensive scientific work in laboratories and expensive trials in metallurgical plants. Millions of dollars have been spent in order that there may be full realization of the properties added by chromium, and means developed for utilizing these properties in industry and home.

Chromium irons and steels have contributed to engineering and chemical advances which have speeded the day's work, enlarged leisure and enhanced the pleasure of spare hours. They are helping mankind in the fight against corrosion, filling gaps in engineering materials and removing limitations in apparatus, machinery and processes.

Prepared from information supplied by Fred. M. Becket, Member, American Institute of Mining and Metallurgical Engineers, President, Union Carbide and Carbon Research Laboratories, New York.

MOTION PICTURES BY ANYBODY

Photographic Reversal Process

C. E. K. MEES

Fifty years ago George Eastman got the idea that photography should be possible by anybody interested. The first step forward was gelatine dry plates, in 1880. But cameras and fragile glass plates that had to be loaded in a dark room would never do. By combining the efforts of other persons with his own, by persistent research, and by masterful business methods, Mr. Eastman achieved his ideal in still pictures. Step by step flexible film that could be loaded in daylight, pocket cameras, numerous accessories and universal service, made everybody a potential photographer.

Then Edison and his attempts to picture motion came like a comet. He heard of Eastman's discovery of flexible film and sent Dickson to Rochester to investigate. The purchase memo, dated 2nd September, 1889, for the strip of film which he took back to West Orange is still in the Eastman Kodak Company files. Edison's verdict was: "That's it; we've got it! Now work like hell."

By 1918, motion picture photography had so progressed that the Eastman organization determined to make it possible for the amateur. The situation, relatively, was similar to that in still photography in 1880. Besides, the cost was great—$150 for 1000 feet of film ready to be projected, exclusive of camera, projector, and the expense of getting the picture ($9.00 for enough film to last a minute in the showing). Simplification of equipment and process, and reduction of cost and weight, had to be achieved.

In the way of smaller films was graininess of the sensitizing emulsion when enlarged upon the screen. A photographic image is composed of small clumps of the microscopic silver crystals in the emulsion on the surface of the film. Enlargement in projecting so magnifies these grains that, although they are extremely minute, the detail of the picture is lost if the enlargement be excessive. The process used by professionals also required development of the exposed film as a *negative* and the printing of a *positive* for projection, a large expense.

For the amateur, motion pictures differ from still pictures in the lack of demand for copies. For him, therefore, it was desirable to render the original film available for projection. The preparation of positives directly was well known, but the process commonly used was not suitable for the new purpose.

The method was to develop the exposed film and then dissolve out the silver, leaving the undeveloped silver bromide, which was not affected by the developer because it was not exposed to light. After a fresh exposure to light, this bromide is developed and gives a positive. There were two disadvantages; satisfactory results through only a very small range of original exposures; dependence upon very exact evenness of coating on the film.

Extended research overcame these difficulties by closely regulating the second exposure in proportion to the exposure in the camera. By great ingenuity an automatic machine was devised for treating films from amateurs. At first the regulating of the second exposure was done by skilled operatives, but a more accurate device has been substituted.

One beam of light from a lamp passes through a red filter,

then through the film, to a thermopile, not affecting the film. The other beam "exposes" the film an amount controlled by the vane of a galvanometer in the opening through which the light passes, the galvanometer being connected to the thermopile.

If the film is very transparent and much light falls on the thermopile, it generates enough electricity to move the vane of the galvanometer out of the opening and let the full power of the lamp "expose" the film heavily, and vice versa, and all the gradations between.

By the new reversal method, excellent results are obtained from films with any thicknesses of coatings; variations in the original exposure are almost perfectly compensated, and the pictures are astonishingly free from graininess. Films from customers are fed into a machine at the rate of one every five minutes, and removed from its drying closet about an hour later, ready for projection.

These developments made possible the Cine Kodak with a film 16 millimeters wide, 100 feet long corresponding to 250 feet of "standard" film 35 mm. wide. Each picture is 1 centimeter by $\frac{3}{4}$ cm. or one-sixth the area of the standard picture, 40 to the foot versus 16. For best results it is projected to a screen not exceeding 54 by 40 inches. The cost has been reduced to $1.50 for enough developed film to run a minute when being shown.

The film is non-inflammable. The camera can be held in the hand, is driven by a spring motor and holds enough film for four minutes' running, covering 25 or 30 different scenes. Projectors have been similarly developed. The films can be loaded in daylight. There are processing stations well distributed over the world.

By this system of cinematography anybody can take motion pictures as easily as he previously took still pictures. About twenty-five years ago, Mr. Eastman added a research laboratory to his establishment. In it the developments recorded were carried out.

• Contributed by C. E. K. Mees, D.Sc., Director in Charge of Research and Development, Eastman Kodak Company, Rochester, New York.

AMATEUR "MOVIES" IN COLOR

Color by Physics

C. E. K. MEES

Clerk Maxwell, English physicist, demonstrated in 1861 that any color can be matched by a mixture of three primary colors, red, green and blue-violet. He took three pictures of a colored ribbon, through a red, a green and a blue solution and then projected them in register on to a screen, each through the solution through which it was taken.

For twenty-five years the Kodak Company has researched in color photography, at great expense. In 1909 an inventor in France named Berthon patented a process in which lay the germ of a successful method, but technical difficulties were great and commercial success was not attained. The Kodak Company saw possibilities in this invention in connection with amateur cinematography which it had so successfully developed; it bought the rights. In August, 1928, after costly study, Mr. Eastman and associates had the satisfaction of demonstrating perfected amateur colored motion pictures before Edison, inventor of "movies," and other friends, preliminary to marketing equipment and materials.

For theatres two-color processes usually take advantage of the two sides of the film, putting a picture in each of the two colors on one side in register with the other. Results are not satisfactory for outdoor scenes, and both taking and printing are too complicated for amateurs.

"Kodacolor" is as simple as black-and-white Cine Kodak photography and produces motion pictures in color of highest quality. Anyone possessing a Cine Kodak with an f/1.9 lens has only to insert a color filter into the lens, thread the daylight-loading Kodacolor film in the camera, and send the exposed film to the company. His film will be returned as a black-and-white, and in the ordinary projector will give a black-and-white picture on the screen. If the projector be fitted with a color filter like that in the camera, all the colors of the scene will appear. This removable filter has three separate areas, red, green and blue.

Kodacolor's magic is in the film. The side towards the lens in the camera is covered with longitudinal cylindrical lenses of the film-base material, embossed on it by running between steel rollers. These lenses are about seven times narrower than the dots in a newspaper "half-tone" illustration, or 559 to an inch, visible only under a microscope. The other surface carries the sensitive emulsion.

When the camera trigger is pressed, light reflected from the subject passes selectively through the three-color filter, on through the camera lens, and thence through the tiny longitudinal lenses to the sensitive surface, attacking the latter "from the rear."

The function of the lenses on the film is to guide the rays of light falling upon each tiny area and lay them on the emulsion as three distinct impressions corresponding to the

three filter areas so that the three colors are imaged behind each tiny cylindrical lens as three parallel vertical strips, because the cylindrical lenses are parallel to the stripes of color on the filter.

The width of each minute area of the emulsion is subdivided into three parts related to the three filter areas and affected by light able to pass through the different colors. The sum of these invisibly small affected areas of film constitutes the photographic image.

For example, a red ray from the subject reaches the emulsion on the film at a spot related to the red area of the filter. The "reversal process"* turns this spot into a transparent area, leaving opaque the adjoining, unaffected areas related to the green and blue segments of the filter. The sum of the points on the subject containing red makes a photograph from red light on the emulsion areas related to the red filter area. Similarly with the blue and the green.

In the projector the system is reversed. Behind the film are the red-green-blue filter, the condenser and the source of light. Light coming evenly from the three colors of the filter, superimposed on a screen, appears white. Cover the green and blue of the filter and the screen turns red. Similarly for the two other colors.

With red and green segments both left for white light to shine through, yellow appears on the screen. White minus red gives blue-green. White minus green gives magenta. Varying the areas of each color through which light may shine gives infinite shadings. For any point of the subject the only colors permitted to be projected are those which,

* See Research Narrative No. 146.

on the screen, blend into the corresponding color of that point of the subject.

The film is not colored. The colors are reproduced by the transparency of the film, or by black metallic silver deposited in various degrees of opacity, so as to permit light to shine through one of the three areas of the filter as directed by the tiny film lenses.

Owing to absorption of light by the color filter used in projection, the screen pictures are limited to 22 by 16 inches.

It was necessary to standardize methods of making the lenses on the film, to design and make an emulsion strongly sensitive to green and red light and yet have sufficiently fine grain to enable the minute structure of the separate color elements to be resolved, and, especially, to work out methods by which the film could be developed and "reversed" while retaining the rendering of color. These ends have been attained by research, accumulation of special knowledge, and practical experimentation.

Contributed by C. E. K. Mees, D.Sc., Director in Charge of Research and Development, Eastman Kodak Company, Rochester, New York.

ARTIFICIAL CLIMATES

House Heating and Ventilating

A. C. WILLARD

Man's ability to enclose small portions of space at the surface of the Earth as shelters from inclement weather and to maintain within these enclosures comfortable temperature, humidity, light, and oxygen content, has helped to

extend his habitat into the winter countries. Until recently, even advanced peoples made but small application of the sciences to the heating and ventilating of living and working places, especially detached houses of moderate cost.

In 1918, the National Warm-Air Heating and Ventilating Association made an agreement with the University of Illinois for an investigation of furnace heating problems. Later a typical 9-room frame house was built at Urbana solely for extending and correlating laboratory experiments. It is 33½ feet long by 38 feet wide, has two full stories, basement, and two finished rooms in the attic, a copper shingle roof, and a fully housed brick chimney with 12 by 12-inch flue 35 feet high. The walls were not insulated nor were weather strips used at windows and doors. It is furnished, but occupied only by a caretaker. No cooking nor other housekeeping operations are carried on.

In the snowstorm and cold wave of 13th to 15th January 1927, outside temperatures averaged 3.1° below zero Fahrenheit, ranging from 16 below to 10 above; wind 5 to 14 miles per hour, from northwest and west; snowfall about 6 inches.

At this time the house was heated with a cast-iron, warm-air heater of common type, with a 10-inch smoke pipe, situated near the middle of the basement. From it eleven bare, bright tin heat pipes, of commercial sizes, extended to the rooms and halls. Three ducts connected to registers in the first floor returned cool air from various portions of the house to the heater. There was no cold-air duct from outside. Above the basement rectangular tin ducts in the walls conveyed the warm air.

The heater had a grate of 2.88 square feet area. The fuel was stove-size anthracite of 12,996 British thermal units

per pound. Firing was done at intervals of eight hours. Fire depth ranged from 10 to 8 inches. Coal was consumed at the rate of 3.3 pounds per square foot of grate per hour. The total draft was equivalent to the pressure of 14 hundredths of an inch of water. The chimney could make a much stronger draft; the damper was half closed. Of the total heat in the coal 59 per cent was delivered to the heat pipes; of this portion 80½ per cent was delivered to the room registers.

The 19½ per cent difference, as well as a large part of the 41 per cent not accounted for at the bonnet of the furnace, was not lost, but was distributed through the house by various channels. It was definitely shown that less than 10 per cent of the heat of the coal was actually lost from the house in the flue gas at the chimney top.

In the 48 hours of this severe test, 460 pounds of coal were burned. The temperature of the flue gases leaving the furnace was 498° Fahrenheit; at the base of the chimney, 271; at the chimney top, 152.

The 6 inches of snow on the roof had a marked effect in conserving heat in the house. A humidifier in the furnace kept the relative humidity of the house air at about 18 per cent, hardly enough for bodily comfort at the average temperature maintained.

Was the house warm enough in this sub-zero weather? While the mercury was 16 below outdoors, and when the fire had been without attention for several hours in the night, the average temperatures, at breathing level, in the rooms was 71.6. The averages of 10 readings of a thermometer in each room throughout the test period, were, on the first floor, living room 73.1, dining room 71.4, kitchen

70.3, hall 73.5; second floor, east bedroom 79.5, southwest bedroom 74.7, northwest bedroom 72.1, bathroom 75.2; third floor, east room 69.7, west room 71.3; grand average 73.1° Fahrenheit.

Besides these observations at the breathing level (5 feet above the floor), other thermometers in each room gave the temperatures 4 inches above the floor and 4 inches below the ceiling. For comfort it is desirable that the difference between floor and breathing levels be small. It is affected by locations of warm-air registers and cool-air return ducts, and by several other factors. In this test the greatest differences were: on first floor, 10½°, second floor, 8½°, and third floor, 5½. Observers reported themselves to have been comfortable.

Several types of heaters, different arrangements of heat pipes and cool-air ducts, oil burners, gas burners, and various kinds of fuel will be included in the program continuing through a number of years. Thus Science and Engineering are concerning themselves with the heating of homes as well as the infinitesimal quantity of heat received from a star a million light years away. Our humble tale is less spectacular, but perchance none the less interesting.

Contributed by A. C. Willard, Member, American Society of Mechanical Engineers; Professor, Heating and Ventilation, and Head of Department of Mechanical Engineering, University of Illinois, from Circular No. 15, Engineering Experiment Station (now out of print).

MERCURY POWER

Utilizing a Higher Heat Fall

W. L. R. EMMET

Water power, steam power, gas power, mercury power? For centuries man has utilized the power of falling water. He came to realize that the higher the fall, the greater the power. Only for a generation has he had mechanical devices suitable for the higher falls. The first mills at Niagara Falls used inefficiently but a small fraction of the 164-foot drop. Now water-wheels take practically all the power out of falls twenty times as high. Water cannot be dropped below sea level and so engineers have sought in mountainous country water that falls from high levels. On many streams water is used over and over at successive falls.

More than two thousand years ago, Hero of Alexandria invented an engine using steam power resulting from application of heat to water. A century ago, years after Watt and others had begun to build practical steam engines, ideas of heat were very different from those of today. The hypothesis that caloric (heat) was matter, a subtle fluid, was wrecked by Nicolas Leonard Sadi Carnot, a brilliant young French engineer, who in 1824 published his essay on the motive power of heat. Carnot's great discovery, the basis of all modern heat engineering, was not grasped until William Thomson (Lord Kelvin) interpreted it twenty-six years later.

Carnot taught that heat could be used to do mechanical work in "falling" from higher to lower temperature levels. There must, however, be employed a suitable medium and a

suitable mechanism. Water was already in use as a suitable and abundant medium, by means of boilers and engines as the convenient mechanism. But like the early water wheels, the early steam-power plants could utilize but a small fraction of the fall.

As understanding of Carnot's principle spread and advance of the arts made better mechanism feasible, engineers and inventors endeavored for economic reasons to use a larger portion of the possible heat drop. It saved fuel. Boiler pressures were steadily pushed upward from seven pounds per square inch on the gage till now one small plant is reported to operate at 3,200 pounds pressure.

The higher the pressure, the higher the temperature of steam. Some years ago it was found that the temperature could advantageously be raised above that corresponding to pressure; "superheating" came into wide use. Condensers were invented to utilize more of the lower end of the fall. The feasible discharge level is now the temperature of fairly cool "condensing" water.

But can we go farther up the mountain? Is there some liquid that boils (turns into vapor) at a much higher temperature than water, which can be employed in power equipment? Fifteen years or more ago W. L. R. Emmet conceived that mercury could be so employed and that suitable mechanisms could be made for its use in the temperature fall above that in which water is conveniently employed.

The heat left in the mercury after passing through the engine (turbine), its temperature being then about 435° Fahrenheit, would be used to make steam at a pressure of about 300 pounds, for the second step in the heat fall.

Mercury boils at 675° instead of 212 for water. At the

very moderate pressure of 70 pounds on the gage, mercury vapor has a temperature of 884; at 180 pounds, a temperature of 1000. Consequently high temperatures can be had without excessive pressures.

Mercury differs from water in other properties. It weighs thirteen and a half times as much; it does not wet steel (the usual material for power boilers); it is expensive; its vapor is poisonous; it oxidizes readily.

Several other liquids which boil at high temperature were tested to determine their suitability for the same application. After extensive experiments, however, it became evident that mercury was the only practical liquid for supplementing water as a thermodynamic fluid in connection with the generation of power from coal.

Between that conclusion and the present ability to install complete and dependable plants of acceptable efficiency in central power stations are years of hard work in overcoming difficulties. After preliminary experimentation, a large trial equipment was built and operated in the General Electric Company's shops at Schenectady, in 1915 to 1917.

Construction of a satisfactory mercury boiler proved particularly difficult. The boiling conditions of mercury are peculiar and very different from those of water. Theories concerning its action were tested by circulating mercury with compressed air in glass structures and by boiling it in single tubes of various shapes.

A type of boiler promising reliability in service having been developed, a combined mercury and steam power unit was built for the Hartford Electric Light Company and put into service in 1923. This was the first mercury-vapor power installation in the world. Practical operating ex-

perience and continued experiments have made possible large commercial applications.

A second unit has been installed for the Hartford Electric Light Company. Satisfactory records of the first installation and the subsequent improvements assure the reliability, efficiency and flexibility demanded for central station service and substantial saving of fuel.

Contributed by Alfred D. Flinn, Director of Engineering Foundation, through the courtesy of W. L. R. Emmet, Sc.D., Member, American Society of Mechanical Engineers and American Institute of Electrical Engineers, Consulting Engineer, General Electric Company, Schenectady, New York.

ALUMINUM PLATING

A New Means for Protecting Iron

D. B. KEYES AND SHERLOCK SWANN, JR.

Gold, silver, nickel, copper, zinc have for years been applied in thin coatings to objects of other metals and of some other materials also, to protect them from corrosion, to give them a more pleasing appearance, or for other purposes. Electroplating has become a common method. In recent years we have been taught the uses of chromium plating. (Research Narratives 119 and 145.)

Why not aluminum plating? This relatively weak and soft metal has properties which might advantageously be imparted to the surfaces of many things made of iron and steel. Pure aluminum resists ordinary atmospheric corrosion and is little attacked by certain concentrated acids—nitric and acetic, for example. Metal tubes and pipes are

used extensively in petroleum refineries. Sulfur compounds in petroleum will not corrode aluminum tubes to any appreciable extent, even at high temperatures, but they damage iron and steel rapidly. Why not combine this useful resistance of aluminum with the strength of steel? Some research men at the University of Illinois and other laboratories have been trying to find out how.

Electroplating is not so simple as the uninitiated may surmise. Platable metals do not perform alike. Aluminum appears to be emphatically non-conformist. One possible use of aluminum plating is the protection of steel tubes which are the major part in the "economizers" in most steam power plants. These tubes have hot water inside and hot flue gases outside. Flue gases in many places contain large quantities of sulfur compounds derived from the fuel. Aluminum plating on the outsides of these tubes, if economically feasible, would save great sums of money consumed by frequent replacements. In locomotives, in petroleum stills, in cylinders for storing compressed gases and in many other pieces of chemical and mechanical equipment in numerous industries there are opportunities for great technical and economic betterments from use of aluminum plating.

Attempts to electroplate with aluminum by methods usual with other metals proved unsuccessful. Time and again ingeniously devised apparatus was set up in the laboratory and its cell filled with water in which some "salt" of aluminum had been dissolved. "Salt" here means a substance made by letting an acid combine chemically with a metal. Objects prepared for plating were put into the cell and connected to its poles. The current was turned on and given a

chance to do its work. Time after time when the specimens were removed they were not plated with aluminum. One after another all the common aluminum salts were tried in water solutions and variations were made in apparatus and methods. In no instance did any plating occur.

Other solvents for the aluminum salts, having different electrical properties, were tried. The current acted on the aluminum, but again no aluminum was plated. At the end of one of the experiments, an assistant thought he had it. He brought in a copper plate which had been coated with a grayish deposit after having been for some time in a cell filled with a mixture of aluminum formate and formic acid. Unfortunately, careful tests proved the absence of aluminum.

Systematic research was undertaken, beginning with certain aluminum organic compounds having low melting temperatures, to find one from which the metal could be satisfactorily deposited by the electric current upon objects to be plated. For one successful experiment it was necessary to cool the reaction chamber by means of ice to about 20° Centigrade. In another experiment the temperature was maintained at 100° Centigrade by an oil bath.

Experiments were made with complex compounds named Grignards, after the chemist who discovered them. Aluminum Grignards were dissolved in ether. It was necessary to cool the solution with ice to keep the ether from boiling off. Disappointments in some trials showed conclusively that no aluminum would plate from the Grignard-ether solution if any moisture were present.

In another experiment a mixture of tetra-ethyl amonium bromide aluminum bromide complex was tried. This mixture had to be heated to the boiling temperature of water to

bring about electrolysis. Furthermore, it was found necessary to use in this mixture a quaternary amonium salt (a salt made of four radicals*), for otherwise as the molecules of the salts were separated in the process, if any hydrogen became attached to some of the nitrogen in the mixture, it appeared to prevent plating.

This research, begun in 1927, still goes on, encountering and overcoming one difficulty after another. As a result, aluminum has been plated on to other metals so as to produce a satisfactory coating. However, these laboratory successes are only of scientific interest as yet. The road to practical aluminum plating on a commercial scale may be long and bumpy. Between these laboratory achievements and dividend-paying industrial success much "patient money," as John E. Teeple has aptly dubbed it, will, doubtless, have to be invested.

As so often occurs in scientific research, systematically pursued by well trained men, the new facts being gathered give promise of becoming useful in other ways also. The new general method of electroplating which is being developed may be utilized, because of the purity of the product, for investigating the atomic weights of metals, to add to scientific knowledge. It may also eventually overcome difficulties in plating with titanium, tungsten, boron, chromium, beryllium, cerium, tantalum, and still other metals.

Data contributed by D. B. Keyes, Professor of Industrial Chemistry and Sherlock Swann, Jr., Research Assistant in Chemical Engineering, University of Illinois.

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* A radical is a group of different atoms acting in a compound like a single chemical element.

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